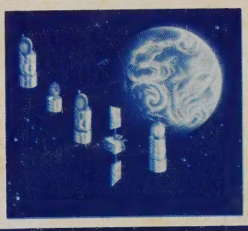
A Technical Description

Telesat

Télésat Canada



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This Technical Pamphlet has been prepared by the Engineering and Operations Departments of Telesat Canada for the purpose of setting out, in a brief and concise manner, the development and operation of the Canadian Domestic Satellite Communications System.

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The material herein is of an informative nature only and is not to be considered as an instruction manual for the development of a system similar in any manner or related to the one described. The greatest care has been used to ensure the accuracy of the material; however, Telesat Canada assumes no responsibility for any inaccuracies contained herein or for any liability which may arise as as result of reliance on any of the information set out in this pamphlet.

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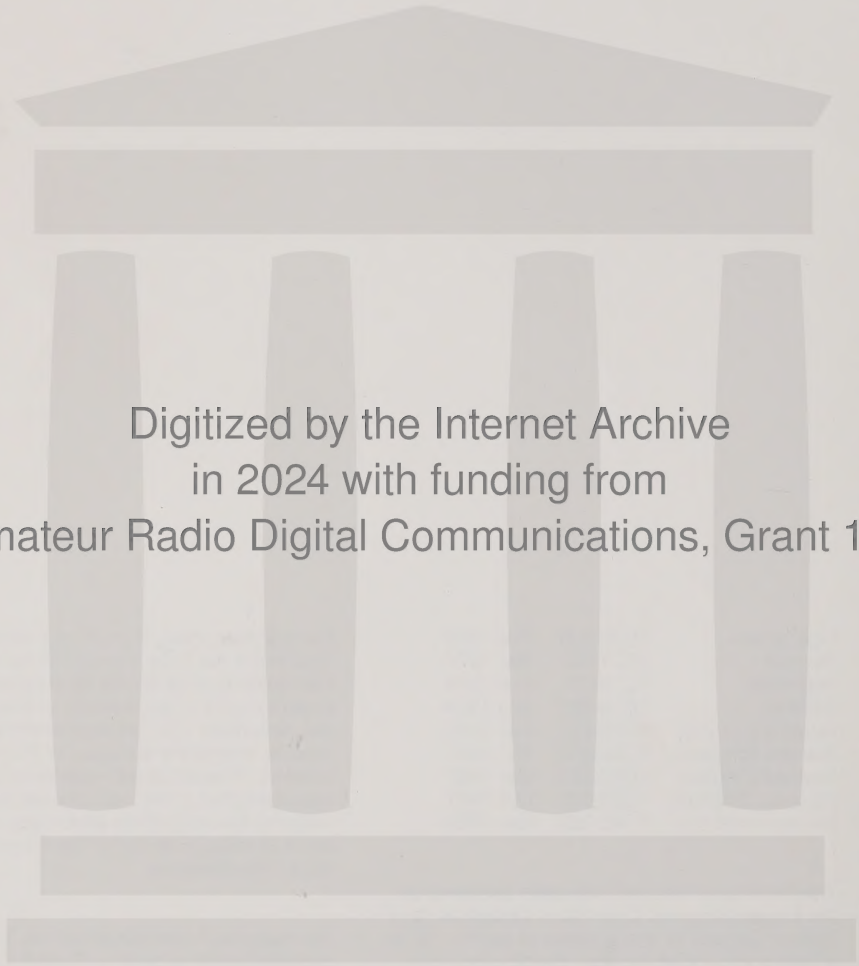

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Telesat

Telesat Canada

A Technical Description of the Canadian Domestic Satellite Communications System

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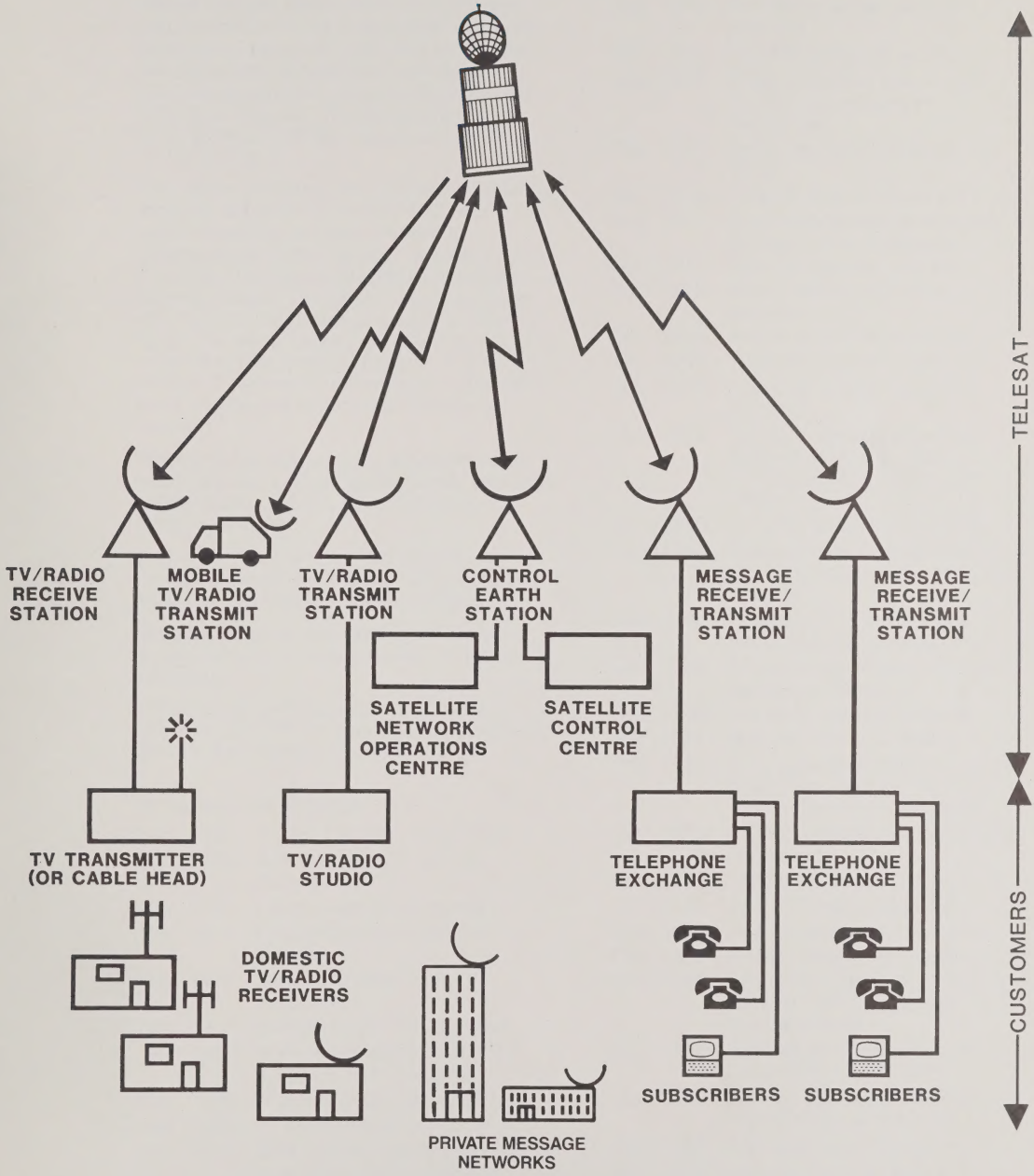
Chapter I
Introduction



Introduction

1

Telesat Canada, established as a Canadian corporation by an Act of Parliament, came into being on 1 September 1969. The corporation was authorized to install and operate a commercial satellite communications system throughout Canada. These objectives have been achieved with the start of service on 11 January 1973.

The Telesat Satellite Communications System includes active 6/4 GHz and 14/12 GHz communications repeater satellites in geostationary orbits, Tracking, Telemetry and Command facilities, a Satellite Control Centre, a Satellite Network Operations Centre and over one hundred earth stations of several different types. The earth stations are linked by terrestrial systems to telephone exchanges, TV and radio studios, TV and radio transmitters, cable head-ends, mining and construction camps, as required.

Transportable earth stations are available for short-term use such as sports events, elections, lottery draws, oil spills, news gathering and military exercises.

In addition there are over four hundred non-Telesat, licensed, earth stations receiving TV transmissions from the Telesat satellites.

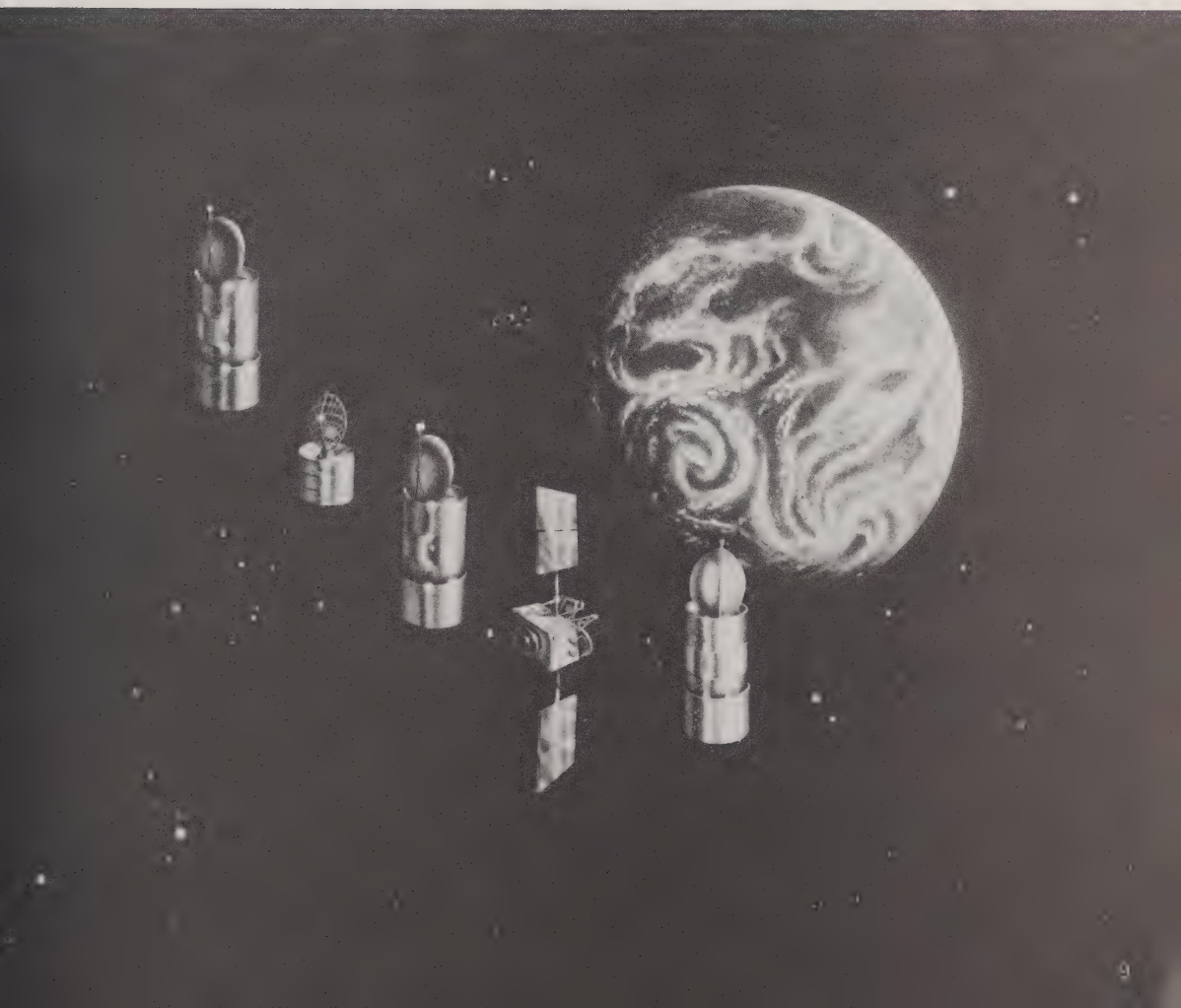
Telesat's expertise and experience are being sought world wide under several consulting contracts.

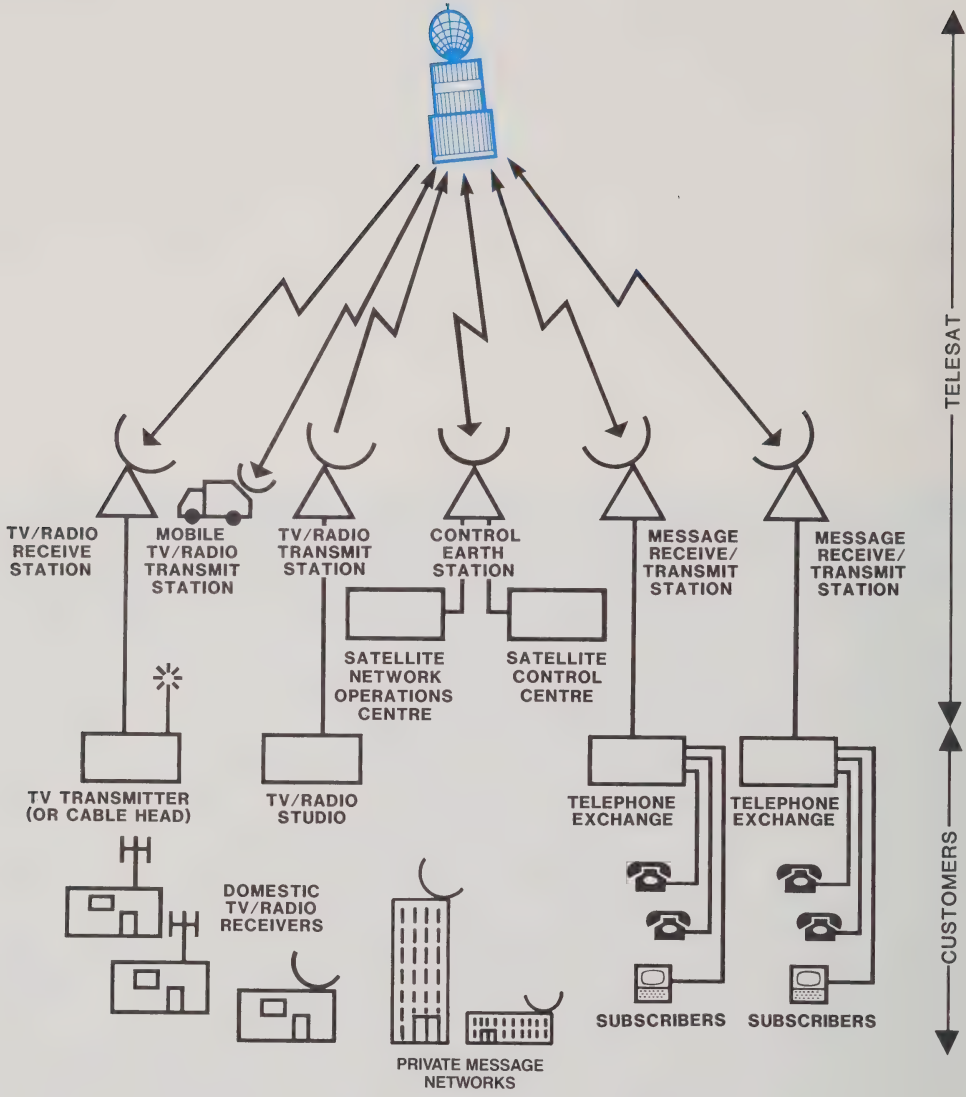
Details of the various elements of Telesat's Domestic Satellite Communications System are given in the following chapters.

A History of Telesat

Sept	1969	Telesat Canada incorporated
Sept	1970	Anik A spacecraft contract awarded
May	1971	Launch agreement signed
May	1971	First earth station contracts awarded
May	1972	Satellite Control Centre established
Nov	1972	Anik A1 spacecraft launched
Jan	1973	Commercial satellite service started (4 earth stations)
Apr	1973	Anik A2 spacecraft launched
Dec	1973	34 earth stations in service
Feb	1974	Start of three-month demonstration of a transportable message terminal in the Mackenzie Delta
May	1974	Demonstration of a message terminal at Isaachsen (78° 47′ N latitude)
Dec	1974	49 earth stations in service
May	1975	Anik A3 spacecraft launched
Dec	1975	Anik B spacecraft contract awarded
Dec	1975	58 earth stations in service
May	1976	First commercial time division multiple access system operational
Dec	1976	Telesat became a member of TCTS
Dec	1976	72 earth stations in service
Aug	1977	Experimental service started at Eureka (79° 49′ N latitude)
Dec	1977	85 earth stations in service
Apr	1978	Anik C spacecraft contract awarded
Dec	1978	Anik B spacecraft launched
Jan	1979	100 earth stations in service
May	1979	Anik D spacecraft contract awarded
Dec	1979	123 earth stations in service. Antenna erected for first commercial 14/12 GHz earth station
Apr	1980	21 TVRO stations sold to CBC
Aug	1980	Transportable message terminal in service on a stabilized oil rig off Sable Island
Sept	1980	First commercial 14/12 GHz transmission of TV programs
Oct	1980	Facsimile transmission of a daily newspaper started
Dec	1980	121 earth stations in service
Feb	1981	Anik A2 and A3 co-located
July	1981	A transportable television transmit station was used in 23 cities across Canada in one month
Oct	1981	6 TVRO stations sold to the Yukon Government
Dec	1981	114 earth stations in service
Jul	1982	Anik A1 Spacecraft retired
Aug	1982	Anik D1 Spacecraft launched
Oct	1982	Anik A2 Spacecraft retired
Oct	1982	Integrated Satellite Business Network TDMA equipment Contract Award
Nov	1982	First regular transmission of scrambled TV programs
Nov	1982	Anik C3 Spacecraft launched on first commercial STS flight
Dec	1982	117 earth stations in service
Jan	1983	First commercial 14/12 GHz message service
Feb	1983	Pay TV broadcasts started (14/12 GHz)
Apr	1983	Four Light Route TDMA stations in service
June	1983	Anik C2 spacecraft launched

Chapter 2
The Spacecraft System




TV/RADIO RECEIVE STATION
MOBILE TV/RADIO TRANSMIT STATION
TV/RADIO TRANSMIT STATION
CONTROL EARTH STATION
MESSAGE RECEIVE/ TRANSMIT STATION
MESSAGE RECEIVE/ TRANSMIT STATION
SATELLITE NETWORK OPERATIONS CENTRE
SATELLITE CONTROL CENTRE
TV TRANSMITTER (OR CABLE HEAD)
TV/RADIO STUDIO
TELEPHONE EXCHANGE
TELEPHONE EXCHANGE
DOMESTIC TV/RADIO RECEIVERS
SUBSCRIBERS
SUBSCRIBERS
PRIVATE MESSAGE NETWORKS
TELESAT
CUSTOMERS

The Spacecraft System

2

Introduction

Orbital positions are available, between 104° W and 118° W, to accommodate Anik B, two Anik D and three Anik C satellites. In 1983 there are one Anik A, one Anik B, two Anik C and one Anik D series satellites. A further Anik C and an Anik D spacecraft are in storage awaiting launch in 1984. Note: *Spacecraft* is the term used before launch and *satellite* after launch.
Each spacecraft consists of four major systems:

i) A Structure System to support all spacecraft hardware, and to ensure its survival during ground assembly, test, handling and the subsequent launch.

ii) A Bus System to provide the power and all the services required to control the satellite's orbital position and attitude, and to allow commanding of control functions and telemetry of data vital to the satellite's operation and health.

iii) A Communication System, or payload, to relay ground originated microwave signals, in the 6/4 GHz and/or 14/12 GHz bands, (which are designated for fixed satellite services), and

iv) An Apogee Kick Motor (AKM), using a solid propellant ignited on command, to inject the satellite from the inclined elliptical transfer orbit into an equatorial, near circular, drift orbit at synchronous altitude.

Precise station-keeping maintains the satellites in orbit within close tolerances of their nominal positions and attitudes (see Chapter 3). This allows the use of fixed antennas at most earth stations within the footprint of the satellite's antenna.

The useful life of a satellite is normally limited by the amount of fuel available for station keeping. Anik A1 and A2 were each designed for seven years of life but served for ten. However, the usefulness of a satellite may degrade during its life as the batteries deteriorate and active electronic components fail. For this reason redundancy is used wherever possible to maintain the satellite's usefulness during its design life.

A comparative Table of Characteristics of the Telesat satellites is shown in Table 2.1.

Details on each series of operational satellites, possible future spacecraft, and the launch vehicles, are given in the remainder of this Chapter.

Table 2.1 Comparison of Anik Series Spacecraft

	UNIT	ANIK A	ANIK B		ANIK C	ANIK D
Transfer Orbit Weight	kg	560	920		1140	1217
Height (On-station)	m	3.4	3.28		8.57	8.57
Body Width	m	1.78	2.05		2.18	2.18
Max. Dimension (On station)	m	3.4	9.54		6.57	6.57
Stabilization		Spun	3 Axis		Spun	Spun
Frequency Band	GHz	6/4	6/4	14/12	14/12	6/4
Number of Channels		12	12	6	18	24
Number of TWTA's		12	12	4	20	24
Channel Bandwidth	MHz	36	36	72	54	36
Antenna Coverage		All Canada	All Canada	4 Spot Beams	S. Canada 4 Spot Beams + Switching	All Canada
Saturation Flux Density – Maximum	dBW/m²	−80	−81	−86 (−81)	−83.5 (−81.0)	81
Antenna Pointing Accuracy N-S		±0.25	±0.15		±0.05	±0.20
E-W		±0.10	±0.15		±0.05	±0.05
TWT Rated Power Output Power	W	5	10	20	15	11
Battery: Nominal Capacity	AH	7	17		17.3	17.3
Number		2	3		3	3
Array Capacity	W	235	620		800	800
Design Life	yrs.	7	7		10	10
Mission Life (Minimum)	yrs.	—	—		8	8
Launch Dates			Dec. 78			
1		Nov. 72			May, 1984	Aug. 1982
2		Apr. 73	—		June 1983	Oct. 1984
3		May 75	—		Nov. 1982	—

Anik A Spacecraft

Anik A spacecraft were launched in November 1972, April 1973 and May 1975, by Thor-Delta launch vehicles, from the Eastern Test Range in Florida (USA). Anik A1 was retired in July 1982 and Anik A2 in October 1982.

The Anik A spacecraft are spin stabilized with a despun antenna oriented to give all Canada coverage in the 6/4 GHz bands. Each satellite has twelve high capacity microwave channels and can use ten channels continuously with two in standby.

A photograph of an Anik A spacecraft is shown in Figure 2.1. The subsystems can be seen in more detail in Figure 2.2.

Figure 2.1 Anik A Spacecraft

Bus System

The structure and bus systems of the Anik A spacecraft are similar to those of the Anik C and Anik D spacecraft, with the exceptions that in the Anik A spacecraft the antenna is erect at launch, the communication shelf spins and there is no extendible solar array.

Communications System

The Communications System consists of the Transponder and Antenna Subsystems.

Transponder Subsystem

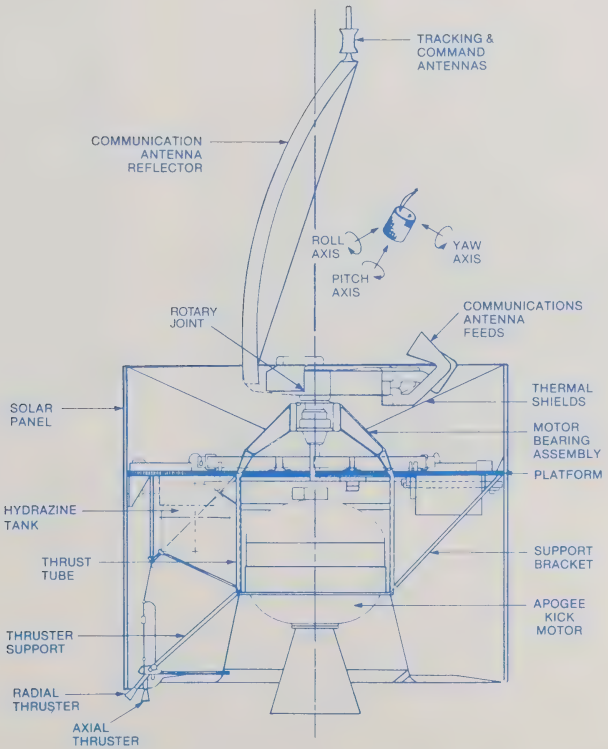
The Transponder Subsystem is a channelized microwave repeater operating in the 6/4 GHz bands. The repeater block diagram is similar to that for Anik B (Figure 2.7). It is an all microwave, fixed gain, single conversion, twelve channel design in which each channel is an independent transponder with a bandwidth of 36 MHz. Channel centre frequency separation is 40 MHz. The frequency and polarization plan is the same as that for Anik B (Figure 2.6). As with all Telesat's current satellites, Travelling Wave Tube Amplifiers (TWTAs) provide the necessary output power.

The only active equipment common to all channels is a switched, redundant, wideband receiver. This translates the received 6 GHz carriers to 4 GHz and amplifies them to an intermediate power level prior to channelization.

Antenna Subsystem

The Antenna Subsystem comprises the parabolic reflector, with its associated feeds and rotary joint for communications signals, and the telemetry transmit bicone and command receive cloverleaf antennas. The rotary joint provides the signal path between the spinning transponder and the despun antenna. The communications antenna beam pattern is shaped to provide all Canada coverage similar to that for Anik B (Figure 2.10). The received signals are vertically polarized and the transmitted signals are horizontally polarized.

Figure 2.2 Anik A General Configuration



Anik B Spacecraft

The Anik B spacecraft was launched in December 1978 by a Delta launch vehicle from the Eastern Test Range in Florida.

It is a three-axis stabilized spacecraft designed to provide all Canada coverage in the 6/4 GHz band (twelve channels) and four spot beams in the 14/12 GHz band (six channels).

A photograph of the Anik B spacecraft in test is shown at Figure 2.3 and a drawing of the satellite on station is at Figure 2.4.

Structure

At the centre of the Anik B spacecraft is a cylinder above a conical adaptor which houses the AKM. The cylinder supports six panels, which create a box-like unit, and deployable solar panels complete the structure. The top, earth pointing, panel carries the antenna subsystem and a base panel closes the bottom. Two opposing panels (North and South) carry most of the internal satellite components and the last two panels (East and West) have openings through which the propellant tanks partially protrude. The base panel is of aluminum honeycomb on an aluminum beam grid, the other panels are of aluminum honeycomb construction. See Figure 2.5.

Figure 2.3 Anik B Spacecraft (Launch Configuration)

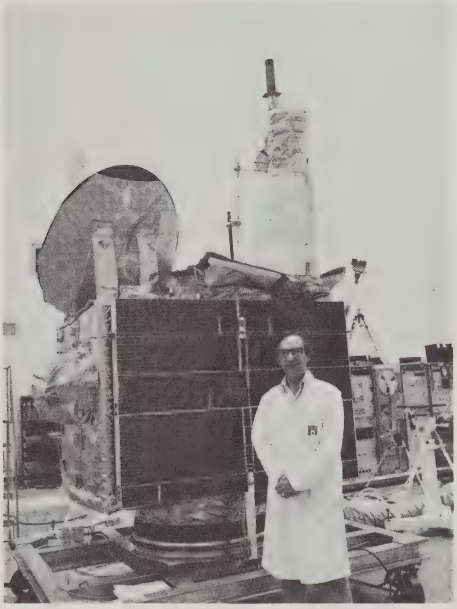
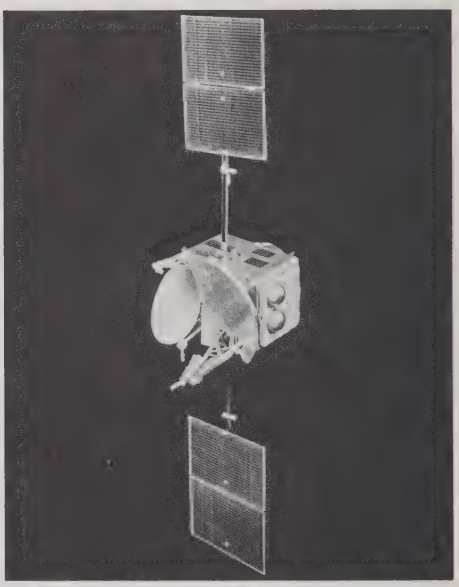


Figure 2.4 Anik B Satellite



Bus System

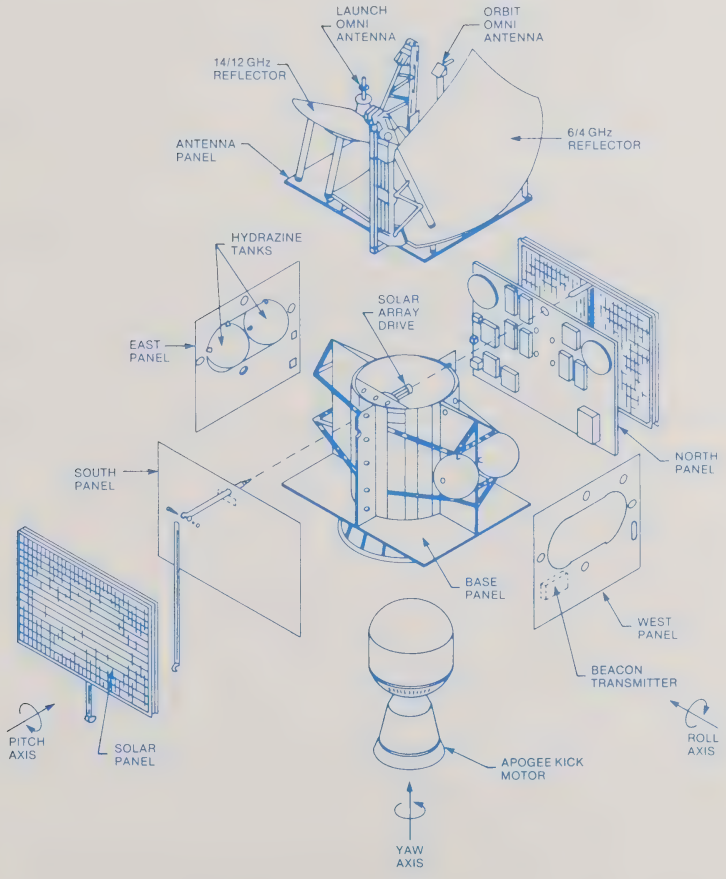
Attitude Control Subsystem

The on-board attitude Control Subsystem provides 3-axis stabilized control of the satellite in geostationary orbit by the use of a momentum wheel and magnetic torquing. Servo-controlled exchanges of momentum between the wheel and the spacecraft main body are used to maintain pitch attitude. Roll and yaw attitude are controlled by magnetic torquing with back-up thruster control. An earth sensor assembly provides attitude sensing to the control logic, and all major elements of the subsystem are redundant. Thrusters are employed to dump momentum built up in the momentum wheel as a result of manoeuvres, and as a result of the effects of solar pressure.

Command, Ranging and Telemetry Subsystem

Command and Telemetry signals are routed through either the launch or orbit omni antennas and the main communications antenna. The command receivers demodulate the 6 GHz uplink carrier to obtain either the Frequency Shift Keyed (FSK) command tones or the ranging subcarrier. Redundant Command Logic Decoders distribute commands to the satellite systems. A Central Logic Processor controls thruster, relay and pyrotechnic commands and has a programmed feature for thruster control during attitude manoeuvres.

Figure 2.5 Anik B Major Components



The ranging system uses the command receivers and the beacon transmitters as a transponder.

The Redundant Telemetry Module performs telemetry commutation, sampling each of the 128 telemetry channels of on-board data, every two seconds, to form the PAM stream. Some analog channels contain up to four bits of digital information. The Pulse Amplitude Modulated (PAM) signal is amplified and transmitted by the beacon telemetry transmitter, and a dwell mode enables any of the 128 telemetry channels to be continuously sampled. The beacon transmitters have a commandable high power mode for use in any manouevre which might result in loss of pitch lock, in which event all signals are routed through the orbit omni antenna. Command verification is obtained by automatic interruption of low priority PAM or dwell data. Selection of high priority PAM or dwell data prevents command verification interruption of data.

Reaction Control Subsystem

The Reaction Control Subsystem (RCS) is used to reorient the satellite spin axis during transfer orbit, to correct for injection errors and to provide synchronous orbit stationkeeping, attitude and momentum control.

The RCS consists of two half systems each having two hydrazine fuel tanks feeding six thrusters, two on each of the North, East and West panels. Valves provide separation of the two half systems and isolation of fuel from the thrusters. A failure in either half system can be isolated by means of the valves and the remaining half system used to continue the mission.

Thermal Control Subsystem

The Thermal Control Subsystem uses heater-augmented, passive, thermal control. The passive surface-finish and insulation elements of the subsystem accommodate the seasonal or orbit variations in solar inputs. The heaters compensate for the wide range of internal heat dissipation caused by the number of transponder channels in operation and the state of the electrical power subsystem. All heaters are controllable by ground command and some are further regulated by thermal control switches.

Electrical Power Subsystem

The Electrical Power Subsystem provides power to operate the satellite systems through all orbital phases.

During liftoff, power is provided from three nickel-cadmium batteries. During transfer orbit, drift orbit and while in non-eclipse operation, the solar arrays supply power to the main satellite unregulated bus for all except occasional peak loads. The batteries are maintained at full charge by a continually applied trickle charge, and any excess solar array power is dissipated by a partial shunt assembly. During eclipse the batteries assume the full load.

A solar array drive mechanism rotates the solar panels at one revolution per day to keep them sun oriented. The power supply electronics unit controls the battery charging rates, the sequence of battery conditioning, and limits the maximum bus voltage. Input converters in each subsystem convert the unregulated bus voltage to meet the specific requirements.

Communications System

The Communications System consists of a 6/4 GHz Transponder Subsystem, a 14/12 GHz Transponder Subsystem, an Antenna Subsystem and a Power and Telemetry Conditioner.

6/4 GHz Transponder Subsystem

The 6/4 GHz Transponder System has 12 RF channels with channel centre frequency spacing of 40 MHz and useable bandwidth of 36 MHz. The frequency and polarization assignments are shown in Figure 2.6.

The received 6 GHz band signal is amplified by the selected redundant receiver and downconverted to the 4 GHz band. It is further amplified by transistor amplifiers before being separated into twelve, 40 MHz wide, channels by the input multiplexers. Each channel is amplified by its own TWTA and the outputs are combined into two groups of six channels in the output multiplexers for input to the 6/4 GHz antenna. A block diagram of the 6/4 GHz transponder is shown in Figure 2.7.

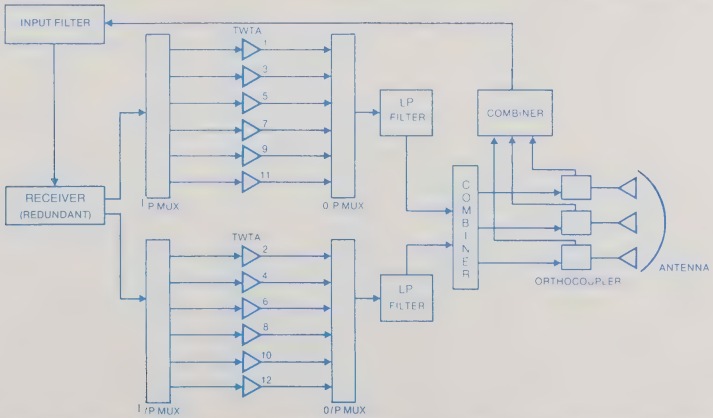
14/12 GHz Transponder Subsystem

The 14/12 GHz Transponder Subsystem has six RF channels with channel centre frequency spacing of 80 MHz and useable bandwidth of 72 MHz. The frequency and polarization plans are shown in Figure 2.8.

The received 14 GHz band signal is amplified by the selected redundant receiver, translated to the 12 GHz band and further amplified by selectable, redundant, GaAs FET amplifiers. The input multiplexers separate the wideband signal into six 80 MHz wide channels. Based on its frequency, and ground commanded switching, each signal is routed via ground commanded gain control units to one of four TWTAs, for further amplification. Normally up to four channels (ie. two TWTAs) may be used at

Figure 2.6 Anik A/Anik B 6/4 GHz Frequency and Polarization Plan

Figure 2.7 Anik B 6/4 GHz Communications Subsystem



one time. Further switching, at the output of the TWTAs, routes signals for combining in the output multiplexers prior to transmission via one of the four down link antenna beams. A block diagram of the 14/12 GHz transponder is shown in Figure 2.9.

The Antenna Subsystem

The Communications Antenna Subsystem is on the satellite earth-facing panel. It consists of two separate assemblies, one for each of the 6/4 GHz and 14/12 GHz transponders. Both receive signals which are vertically polarized and transmit signals which are horizontally polarized. On this panel are also the launch omni and orbit omni antennas.

The 6/4 GHz antenna provides full Canada coverage on up and downlinks. Figure 2.10 shows the basic antenna receive and transmit patterns at 6 and 4 GHz.

The 14/12 GHz antenna provides full Canada coverage on the uplink and has four slightly elliptical spot beams on the downlink (West, West Central, East Central and East). Figure 2.11 shows the basic receive and transmit patterns at 14 and 12 GHz.

To allow for satellite operation from any of the possible orbit locations, an East/West offset can be commanded.

Power and Telemetry Conditioner

This unit processes the transponder related commands for applying power and setting transponder configuration. It also conditions transponder telemetry signals for transmission via the redundant telemetry module and beacon transmitter.

Figure 2.8 Anik B 14/12 GHz Frequency and Polarization Plan

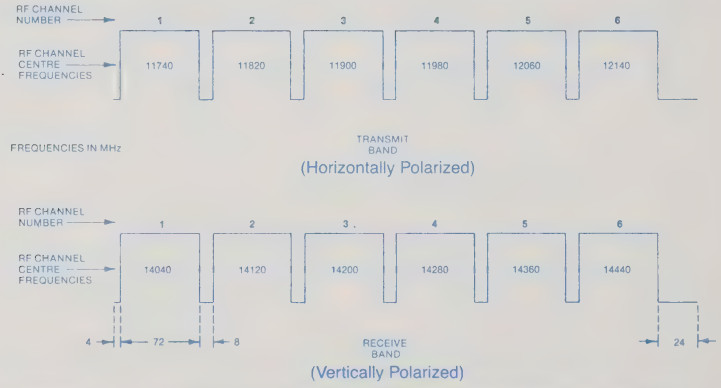


Figure 2.9 Anik B 14/12 GHz Communications Subsystem

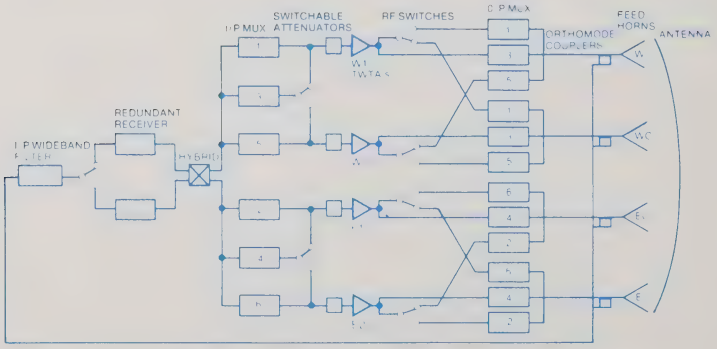


Figure 2.10 Anik B Antenna Patterns 6/4 GHz

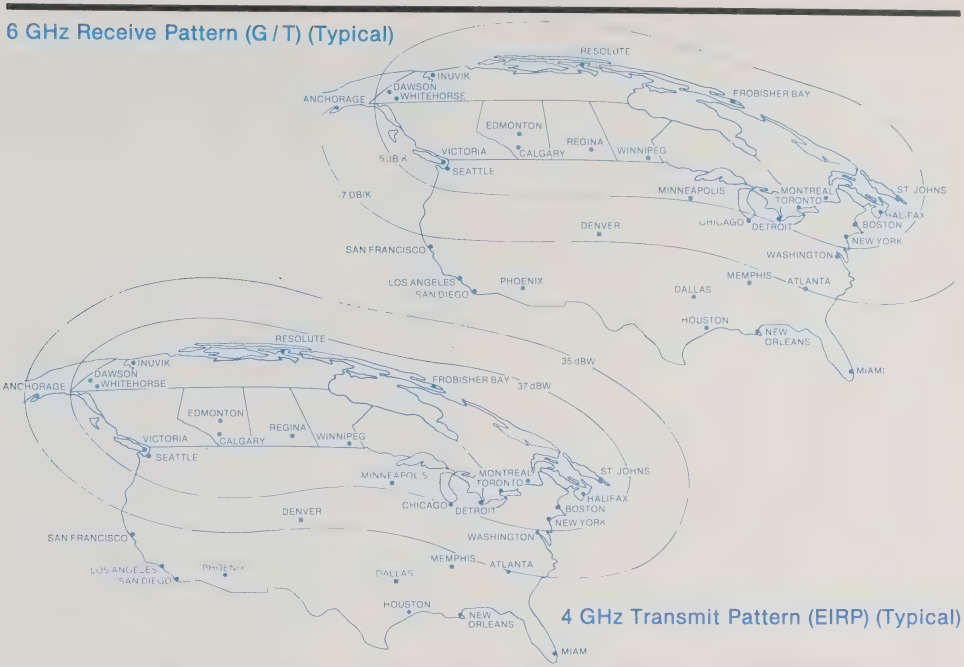
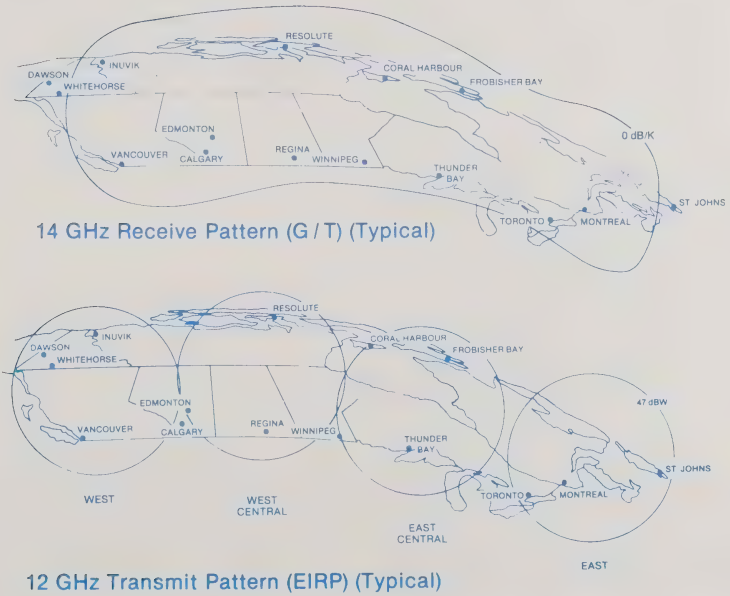


Figure 2.11 Anik B Antenna Patterns 14/12 GHz

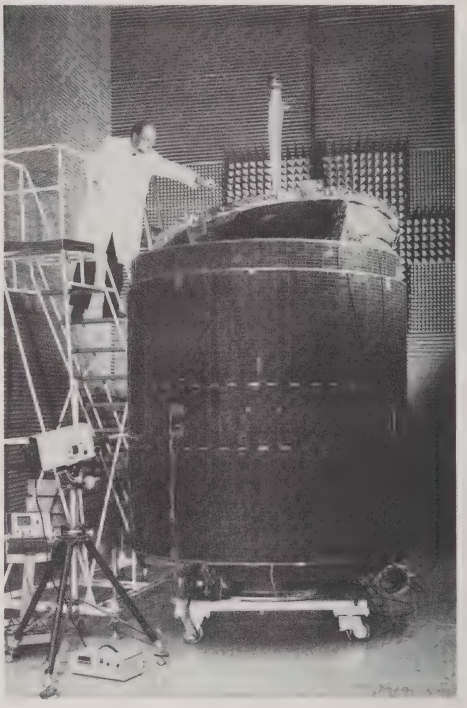


Anik C Spacecraft

The Anik C3 spacecraft was launched in November 1982, and the Anik C2 spacecraft in June 1983, both on the Space Transportation System (Shuttle).

The Anik C spacecraft have a spin stabilized cylindrical configuration with the despun section containing the whole 14/12 GHz communications payload. The spacecraft have sixteen RF channels, to provide a committed fourteen channel minimum requirement at end-of-life, and provide coverage of southern Canada using four transmit spot beams. The spacecraft are designed to be compatible with both the Shuttle and Delta launch systems.

Figure 2.13a Anik C Spacecraft Launch Configuration

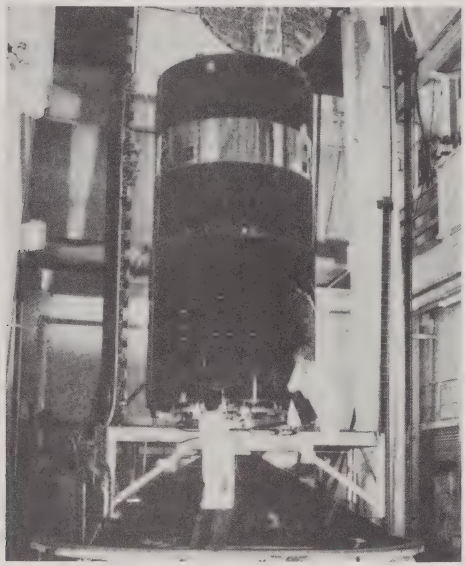


Structure

The main spacecraft structure is shown in Figure 2.12. It consists of a thin wall cylinder and cone, coaxial with the spacecraft, an aluminium honeycomb sandwich platform and a despun shelf. The cylinder houses the apogee motor and supports the platform which carries the batteries, the reaction control thrusters and their propellant tanks. At its periphery the platform supports the forward cylindrical solar array which, in turn, supports the extendible aft solar array. The cylinder/cone also supports the despun shelf through a bearing and power transfer assembly. The despun shelf carries the communication system and the antenna.

Figure 2.12 Anik C Spacecraft Exploded View

Figure 2.13b Anik C Spacecraft on Orbit Configuration



The antenna dish and the aft cylindrical solar panel are stowed at launch, and deployed in orbit to achieve the proper configuration for on-station operations. This approach allows compact and efficient packaging of the spacecraft within the Shuttle Orbiter, and the expanded dimensions in space necessary for solar energy collection and for the erect communications antenna. Figure 2.13 shows the spacecraft in both configurations. The despun section, the communications payload, is locked to the spun section at launch and released in drift orbit, after firing of the apogee motor.

Bus System

Attitude Control Subsystem

The Attitude Control System provides information, about the on-station spin axis attitude, from redundant earth and sun sensors. This telemetered data is used to generate commands to the RCS for any necessary correction.

Antenna Despin Control Subsystem

As the satellite is spinning, it is necessary to despin the antenna and communications shelf to maintain earth pointing. High antenna accuracy ($\pm 0.05°$) in the East-West and North-South directions is achieved by maintaining lock with a pilot signal (beacon) transmitted from a control ground station. The antenna can be controlled in an East-West direction by means of a commanded offset to allow for satellite operation from any of the possible orbit locations.

Telemetry Subsystem

In order to monitor how the subsystems of the satellite are performing, the Telemetry Subsystem is used to transmit analog, status and command register data, using Pulse Code Modulation (PCM). Telemetry data from sun sensor, master index pulse generator and earth sensor, for attitude determination, is transmitted using Frequency Modulation (FM). The command receiver output can also be connected to the telemetry transmitter to form a transponder for ranging purposes.

Command Subsystem

The Command Subsystem, used for addressing the satellite and executing commands in realtime, allows management and control of the satellite. Each command receiver down-converts the 14 GHz signal and demodulates the command tones by means of an FM discriminator. These demodulated tones form the inputs to the command decoders which contain tone filters, threshold detectors and 8-Bit (255 command) digital registers with suitable logic for executing the received command.

Reaction Control Subsystem

The Reaction Control Subsystem (RCS) uses two separate, identical, hydrazine propulsion assemblies to control the attitude and orbit of the satellite. Each of the two propulsion assemblies includes two hydrazine tanks and two thruster pairs mounted just inboard and aft of the solar panel. The subsystem can be operated in either a pulsed or steady-state mode. The nozzle of one thruster of each pair is oriented to fire parallel to the spin axis; these are used for orbit inclination control when fired together in a steady-state mode and for attitude control when fired singly in the pulsed mode. The nozzle of the second thruster of each pair is oriented to fire through the center of gravity and operates only in the pulsed mode to provide drift (E-W) and eccentricity (Range) control. The thrusters are slightly offset in angular alignment in order to provide a tangential thrust vector to allow for control of the satellite spin rate.

Dynamic Balance Subsystem

The spacecraft are balanced before launch but uneven insulation loss, from the apogee motor burn, may result in satellite imbalance (wobble) in orbit. The deployable solar array can be tilted, on ground command, to adjust on-station dynamic balancing.

Electrical Power Subsystem

Power to operate the satellite is derived from solar cells mounted on panels on the exterior of the spinning structure. These panels supply power at 30 V steady state bus voltage for satellite operation and battery charging during sunlight operation. During earth eclipse of the sun, two batteries assume the full load with no decrease in channel capacity or performance. Additional solar strings are used for battery charging, and are controlled by ground command.

The solar array is sized to sustain all sixteen channels at end of life. The batteries are also sized to support this full load during eclipse seasons at a 50% depth of discharge at beginning of life.

Thermal Control Subsystem

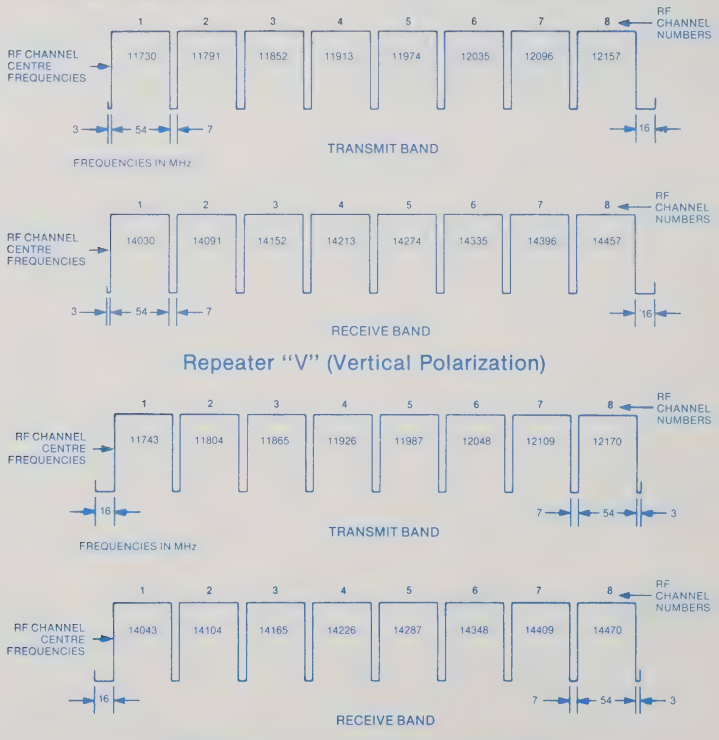
The Thermal Control System uses passive and active elements. Insulating blankets reduce heat loss from the ends of the spacecraft and a sun shield protects the antenna. A thermal radiator, between the forward and aft solar drums, removes heat from the communications shelf. Thermostatic heaters, with command override, are provided for temperature sensitive units such as the TWTAs, batteries and the antenna beacon tracking filter.

Communications System

Transponder Subsystem

The Anik C communications system uses the concept of frequency reuse (two repeaters, Vertical and Horizontal Polarization). This gives a capacity of sixteen RF channels, each with a nominal useable bandwidth of 54 MHz, within a bandwidth of 500 MHz (Figure 2.14). The frequency plan provides an offset of 13 MHz between the centre frequencies of corresponding Horizontal and Vertical RF channels, in the two repeaters, to minimize interference between them.

Figure 2.14 Anik C 14/12 GHz Frequency and Polarization Plan



Two single conversion receivers are multiplexed into sixteen RF channels, eight channels for each polarization (Figure 2.15). Each channel has its own Travelling Wave Tube Amplifier (TWTA).

Redundancy features which have been incorporated are:

i) Three spare communications receivers available to replace the main receivers, by ground command, in the event of malfunction.

ii) A redundancy switching network connecting the sixteen RF channels to twenty TWTAs, with a minimum number of switches, thus allowing up to four TWTA failures without loss of an RF channel.

Antenna Subsystem

The uplink antenna coverage (Figure 2.16) for both polarizations uses single shaped antenna beams. Linear orthogonal polarization, using a shared reflector aperture, provides the necessary isolation between the two uplink beams.

Figure 2.15 Anik C 14/12 GHz Communications Subsystem

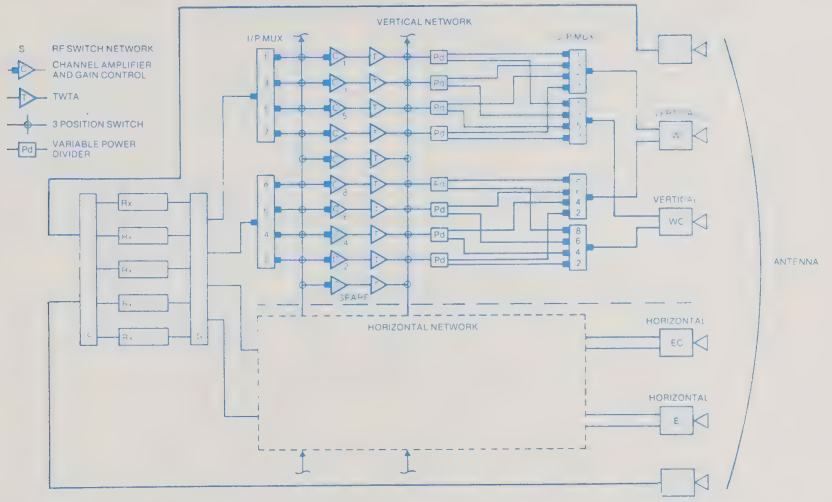
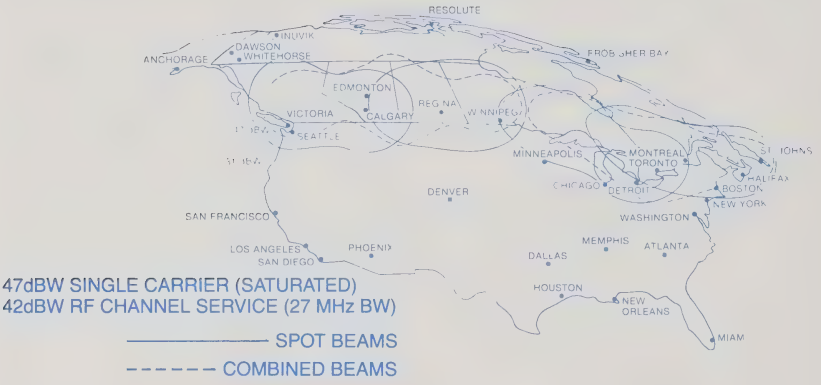


Figure 2.16 Anik C 14 GHz Receive Pattern (G/T) (Typical)

The downlink antenna coverage area is divided into four regions across southern Canada. Each region is approximately 2° East-West by 1° North-South as viewed from synchronous orbit. The contours in Figure 2-17 show the typical EIRP. One repeater serves the western two regions while the other repeater serves the eastern two regions. Within each repeater, each RF channel has output switching to permit service to either of its coverage regions individually or both simultaneously. Hence, the downlink coverage requirements for each RF channnel can be optimized for the type of traffic and service to be provided. Typically the broader area coverage is more appropriate for TV distribution while the narrower coverage is preferred for heavy route message service.

The antenna reflector may be tilted South to give better coverage of the continental USA, or North to improve coverage of Northern Canada. This may require relocation of the pilot control station to a suitable position relative to the footprint, since Anik C spacecraft have active North/South antenna pointing control.

Figure 2.17 Anik C 12 GHz Transmit Pattern (EIRP) (Typical)



Anik D Spacecraft

The Anik D1 spacecraft was launched in August 1982 by an augmented Thor Delta launch vehicle. The Anik D spacecraft is based upon the Anik C design for the bus subsystem but carries a 6/4 GHz communications payload. The spacecraft are designed to be compatible with both the Shuttle and Delta launch systems.

Structure and Bus System

The Anik D structure and bus systems are essentially identical to those of Anik C. The exception is the command receive and telemetry portion, which will operate in the 6/4 GHz frequency bands instead of the 14/12 GHz bands.

Communications System

The Anik D communications system uses the technique of frequency reuse and orthogonal polarization to achieve a capacity of twenty four channels. Each channel has a nominal useable bandwidth of 36 MHz, within a bandwidth of 500 MHz. The frequency plan is shown in Figure 2.18. There will be adequate power for at least 20 channels at end of life.

Transponder Subsystem

The transponder incorporates standby receivers connected in a four-for-two redundancy scheme, the operating receivers being controlled by ground command. The twenty four TWTAs are connected such that they are switchable in a four-for-two redundancy scheme with respect to a prime channel as illustrated in Figure 2.19. For operational use, twelve channels can be designated as primary, the remainder being allocated to pre-emptible traffic or acting as backup. The block diagram of the communication subsystem (Figure 2.20) illustrates the redundant features,

Figure 2.18 Anik D 6/4 GHz Frequency and Polarization Plan

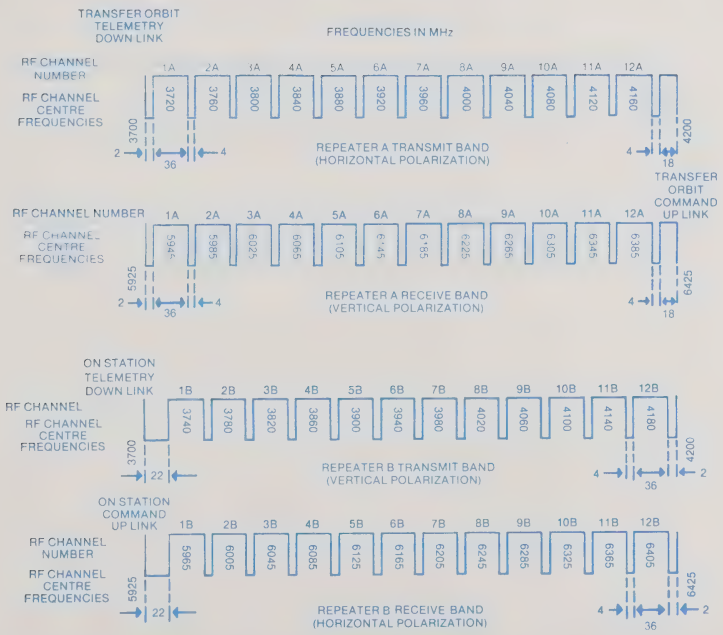
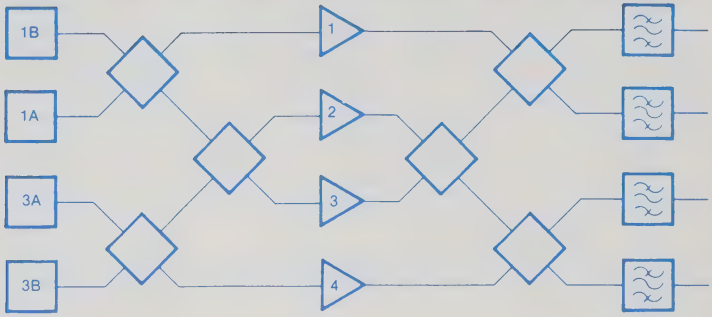
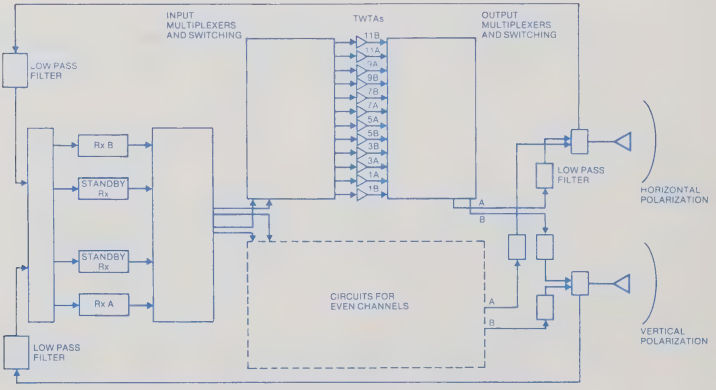


Figure 2.19 Anik D TWTA 4-for-2 Redundancy Switching Arrangement



CHANNEL	1A	3A	1B	3B
TWTA				
PRIMARY	2	3	1	4
BACKUP	1 or 3	2 or 4	2 or 3	2 or 3

Figure 2.20 Anik D 6/4 GHz Communications Subsystem



Antenna Subsystem

The antenna subsystem is similar to that of the Anik C spacecraft, except that full Canadian coverage is provided on both polarizations. Linear, orthogonal, polarization provides the necessary isolation between the two downlink beams. The transmit and receive patterns are shown in Figures 2.21 and 2.22. Anik D satellite reflectors may be tilted south to give better coverage of the continental USA. Note that Anik D has no active North/South antenna pointing control.

Figure 2.21 Anik D 4 GHz Transmit Patterns (EIRP) (Typical)

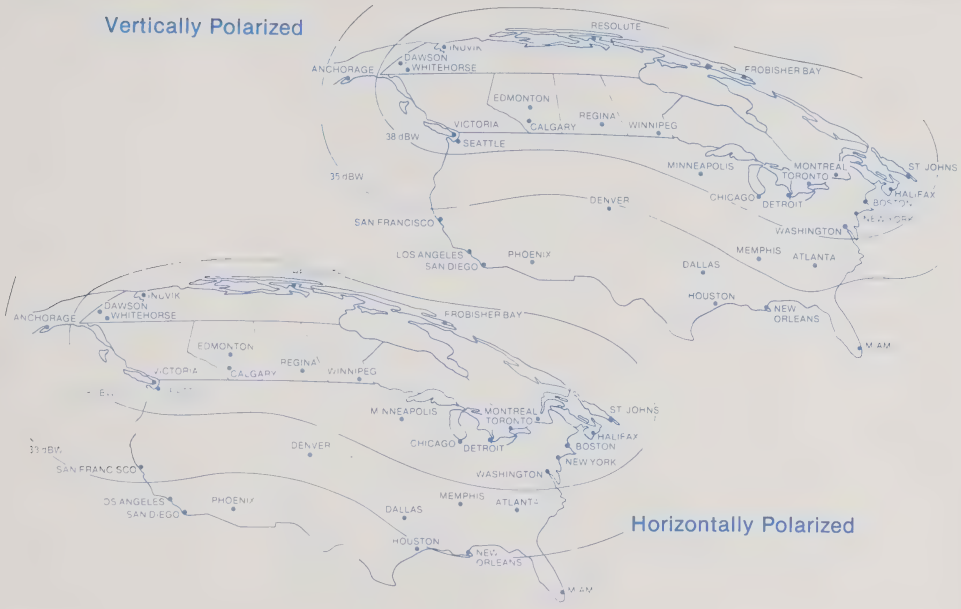
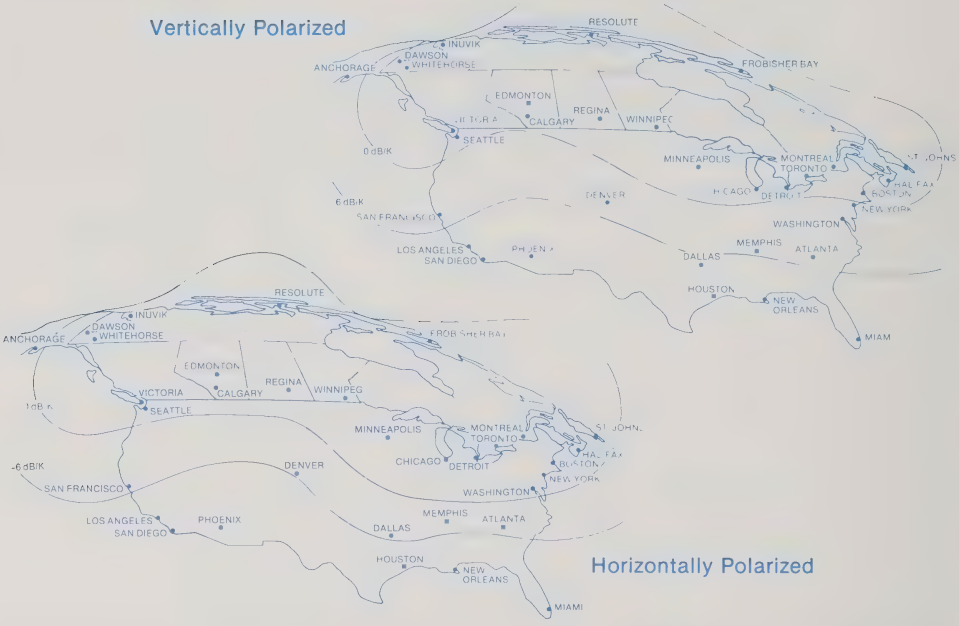


Figure 2.22 Anik D 6 GHz Receive Pattern (G/T) (Typical)



Future Satellites

Telesat is presently initiating preliminary studies for replacement spacecraft for the Anik C and Anik D satellites. Future satellite systems will undoubtedly use new technologies to improve the overall system cost effectiveness. Recent technological advances, which will be considered, include solid state output amplifiers in place of TWTAs, unified propulsion systems (combined AKM and RCS), on-board computers for advanced attitude control and autonomous operation, and nickel/hydrogen batteries. Message, video and teleconference, transborder traffic requirements are expected to grow rapidly in the next decade. The spacecraft antenna may therefore be designed to permit coverage of both Canada and the USA, possibly on a switchable basis.

Increased payload capacity of launch vehicles make larger dual band satellites a possibility that must be considered. However, other considerations, such as orbit frequency coordination, accuracy of forecasting requirements, and replenishment strategies will also have to be included in selecting the spacecraft's configuration.

On-board satellite signal processing, including satellite switched TDMA, will be considered, although at this time it appears unlikely that this will find application in replacement spacecraft for Anik C or Anik D, but rather for future 20/30 GHz systems. In any case more flexibility will be included in feeding channels to different antenna beams.

Launch Vehicles

Telesat's satellites, to date, have been launched by NASA from the Eastern Test Range at Cape Canaveral, U.S.A. Each satellite was injected by its launch vehicle into a highly elliptical transfer orbit with an inclination of about 27° to the equator, a perigee height ranging from 185 to 205 km, and an apogee height ranging from 35 900 to 36 300 km. Some future Telesat satellites may be launched by Ariane expendable launch vehicles from the test range at Kourou (French Guiana).

The Delta Series

The vehicles used to launch the Anik A1 and A2 satellites on 9 November 1972 and 20 April 1973, were modified, and thrust augmented, versions of the Thor Delta — the three stage Delta 1914.

The Anik A3 satellite was launched on 7 May 1975 using a Delta 2914 launch vehicle. This offered a greater payload by using an uprated first stage and a modified second stage engine.

The Anik B spacecraft was launched using a Delta 3914 vehicle, which is upgraded from the 2914 vehicle by the use of larger Castor IV strap on boosters.

The Anik D1 spacecraft was launched using a Delta 3920 vehicle, which is a 3910 vehicle with an upgraded second stage and a Perigee Kick Stage (a Perigee Kick Motor and Payload Attach Fitting) in place of the third stage. An exploded view of this vehicle is in Figure 2.23 and a photograph of its lift off is in figure 2.24.

Figure 2.23 Thor Delta Launch Vehicle

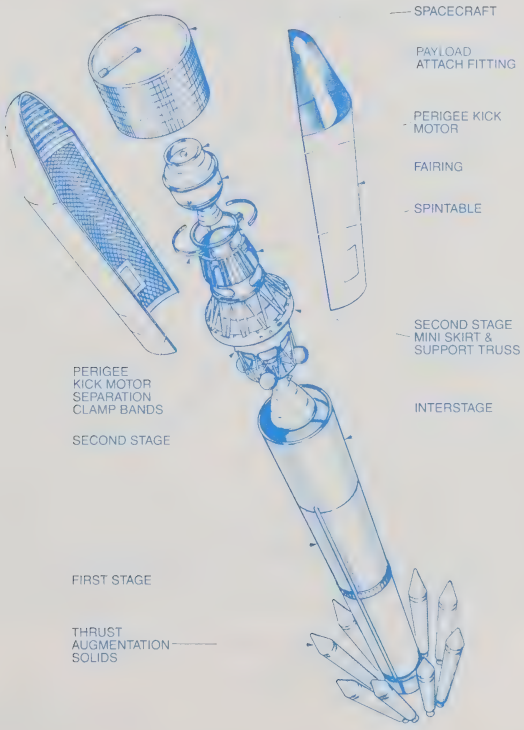
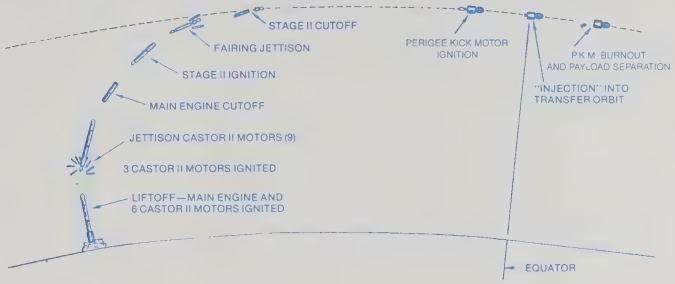


Figure 2.24 Launch of Anik D1

A typical profile of a Delta launch is in Figure 2.25.

Figure 2.25 Delta Launch Sequence Anik A



The Space Transportation System (STS)

This system incorporates a reusable Orbiter vehicle, solid boosters, and an expendable liquid propellant tank. The Orbiter is manned and has a cargo bay of useable dimensions 4.6 m in diameter by 18.3 m in length. Several payloads can be carried in one mission, and costs to the user are proportional to the length/weight fraction occupied (Figure 2.26). A launch-ready view of the STS is in Figure 2.27. The Orbiter and its payloads are put into a circular orbit at an altitude of 296 km. To put a payload into its transfer orbit from this altitude requires the equivalent of the Delta third stage. The general name for such a device is the Spinning Solid Upper Stage — Delta Class (SSUS-D). The unit used by Telesat, for the Anik C and Anik D series of satellites, is the Perigee Kick Stage System (PKSS) shown in Figure 2.28. Since the Orbiter vehicle is manned, the spacecraft and its PKSS must incorporate several special safety features.

Figure 2.26 Anik C Launch Configuration STS

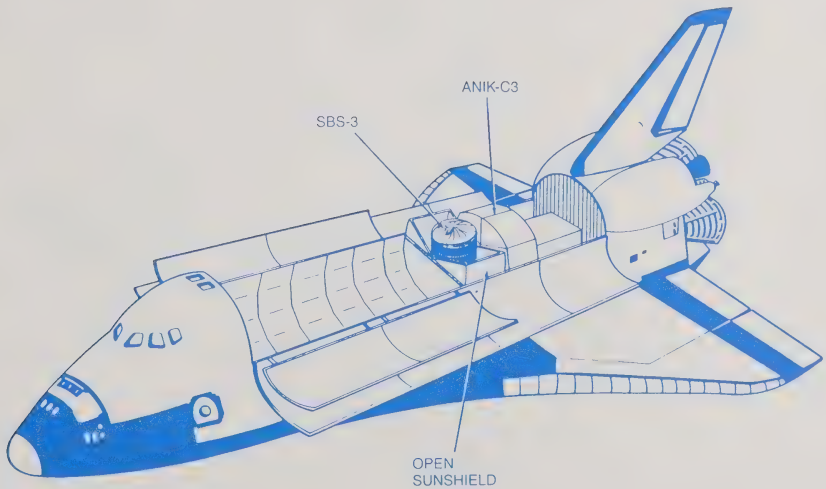
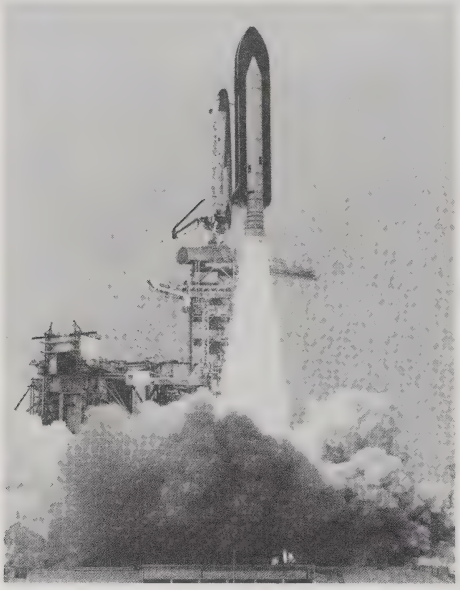


Figure 2.27 The Space Transportation System — at Launch



Before the spacecraft is ejected, it is spun. The crew of the Orbiter can monitor the spacecraft until it reaches approximately 60 rpm and then eject it by means of springs (Figure 2.29). The satellite coasts clear for 45 min. before the solid propellant motor is ignited. In the coast phase, attitude control is achieved by the spacecraft nutation control system which is enabled at a fixed time, after separation from the orbiter, and disabled prior to Perigee Kick Motor firing, by the PKS sequencing system. There are no telemetry or command transmissions in the coast phase.

A typical profile of an Anik/STS trajectory from launch to transfer orbit is shown in Figure 2.30.

Ariane

As a back-up, in case other launch systems are not available, space has been reserved on an Ariane launch in 1985. This Ariane is a three stage, liquid fueled, expendable launch vehicle developed by the European Space Agency (ESA). A device, known as SYLDA, allows two spacecraft to be carried in tandem on one launch vehicle. The launch would be from Kourou, French Guiana, and would put the satellite into a transfer orbit with an inclination of 10° to the equator.

Figure 2.28 Anik C Spacecraft and perigee Kick Stage System

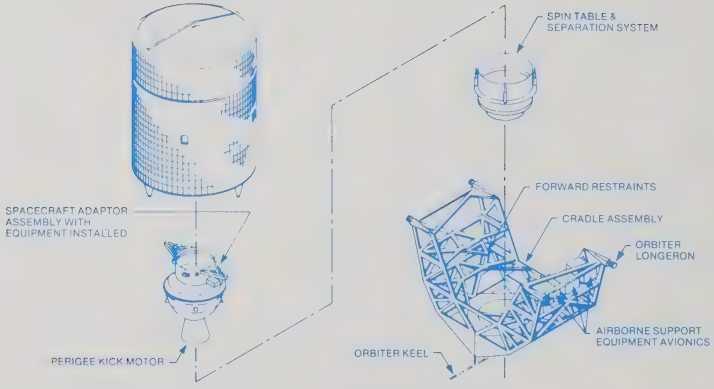


Figure 2.29 Anik C Ejection from STS

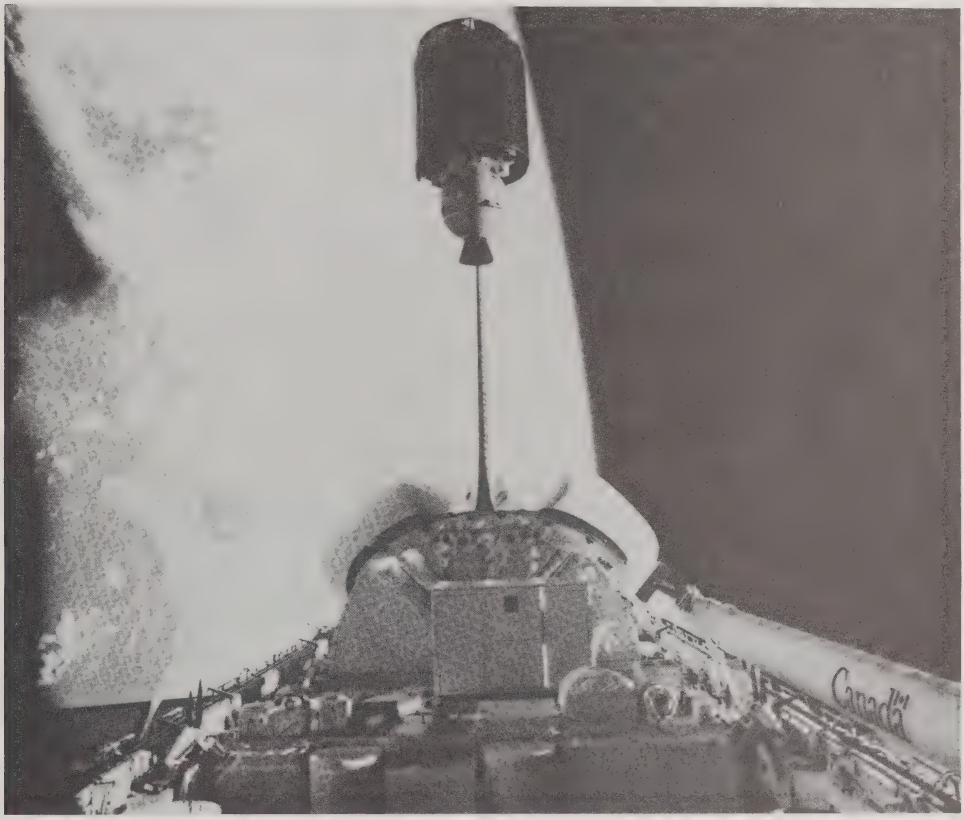
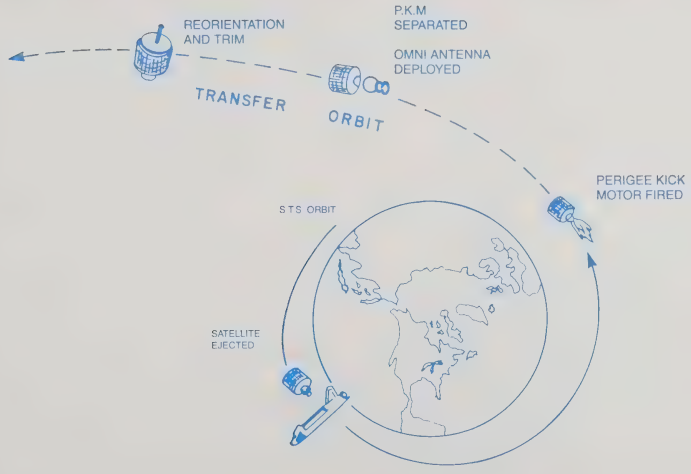


Figure 2.30 Shuttle Mission Sequence (Anik C/Anik D)



The Satellite Control System

3

Introduction

After launch, each satellite is retained in transfer orbit for several revolutions and then injected into a drift orbit by firing the apogee motor. Thereafter the satellite is put into its operating configuration, and guided to its designated position in geostationary orbit, through a series of orbit synchronization manoeuvres (Figure 3.1) commanded from earth.

The satellites are maintained "on station" by periodically firing north-south thrusters to correct the orbital inclination (latitude), or east-west thrusters to correct the longitude. Figure 3.2 demonstrates typical latitude and longitude motions for the Anik C3 satellite. The spinning satellites (Anik A, C and D) must also be controlled in attitude, and Figure 3.3 shows typical attitude motion for Anik C3. The stationkeeping tolerances, currently in use, are listed in Table 3.1. These tolerances change from time to time, depending on traffic requirements.

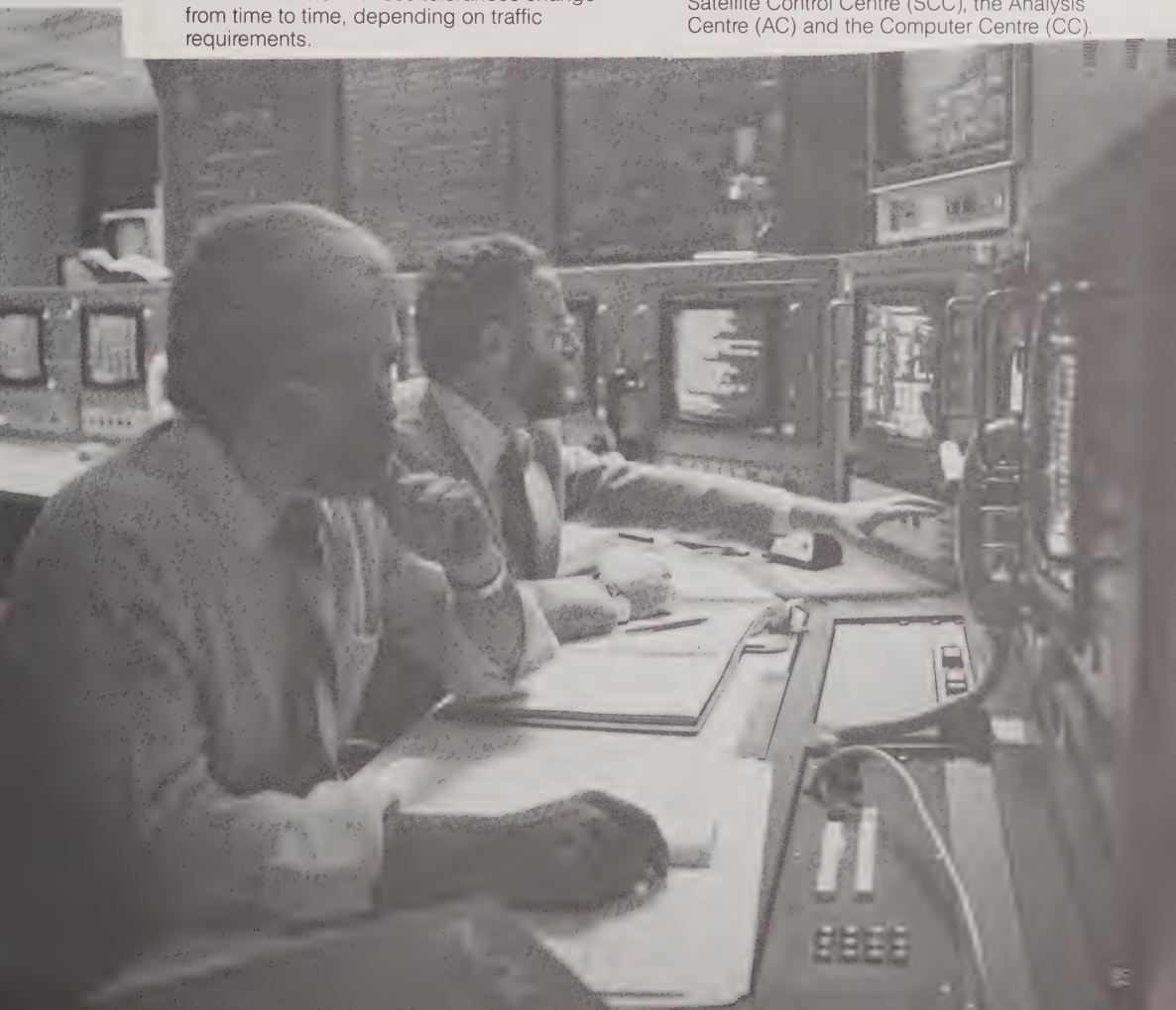
Satellite control is exercised through the Headquarters facilities and the Tracking, Telemetry and Command facilities (TT&C). These TT&C facilities continuously transmit the command carriers, receive the telemetry signals from the satellites and periodically take range measurements.

The hardware and software systems developed by Telesat to control its satellites, through the various orbital phases and subsequent commercial service, are described in the following sections.

The major hardware of the system is shown in Figure 3.4.

Headquarters Facilities

At Telesat headquarters in Ottawa are the Satellite Control Centre (SCC), the Analysis Centre (AC) and the Computer Centre (CC).



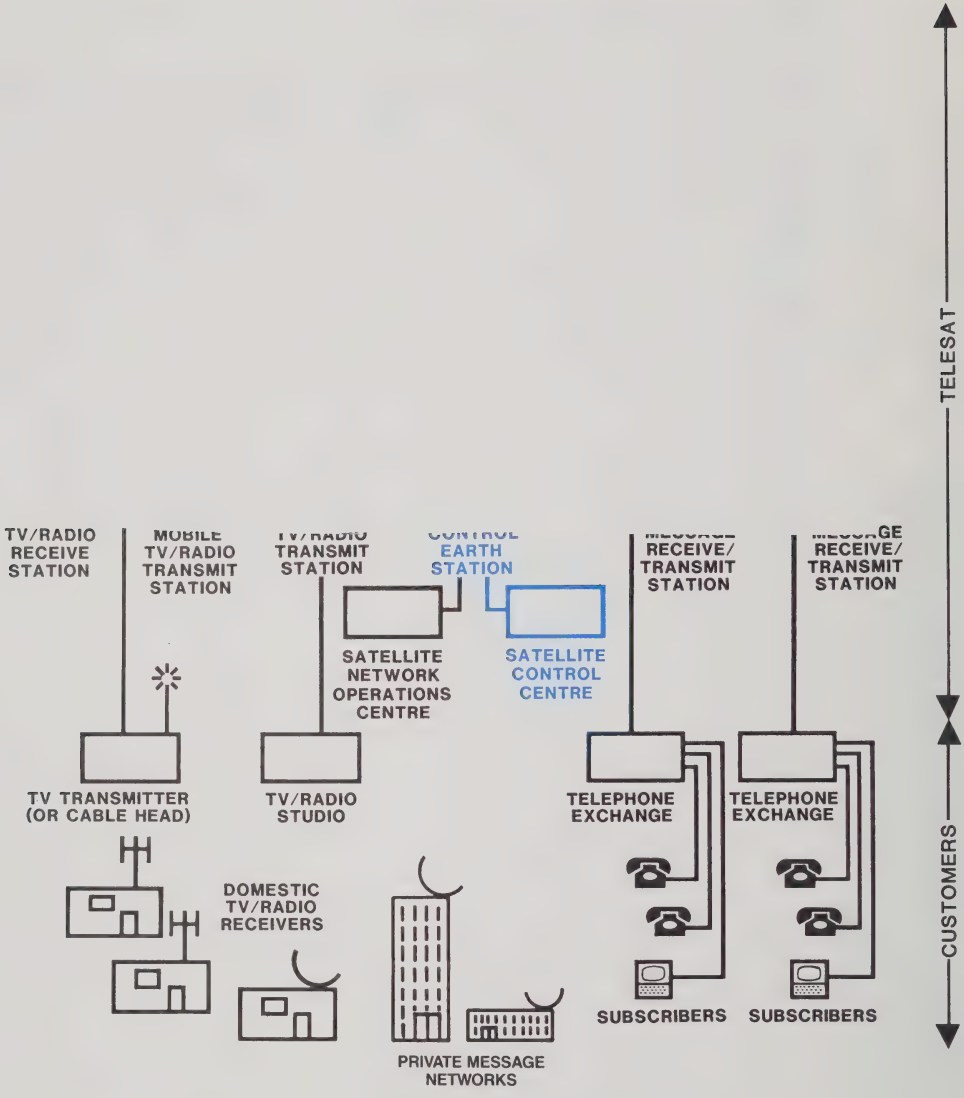

TV/RADIO RECEIVE STATION
MOBILE TV/RADIO TRANSMIT STATION
TV/RADIO TRANSMIT STATION
CONTROL EARTH STATION
SATELLITE NETWORK OPERATIONS CENTRE
SATELLITE CONTROL CENTRE
RECEIVE/ TRANSMIT STATION
RECEIVE/ TRANSMIT STATION
TELESAT
TV TRANSMITTER (OR CABLE HEAD)
TV/RADIO STUDIO
TELEPHONE EXCHANGE
TELEPHONE EXCHANGE
CUSTOMERS
DOMESTIC TV/RADIO RECEIVERS
SUBSCRIBERS
SUBSCRIBERS
PRIVATE MESSAGE NETWORKS

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Figure 3.1 Relationship Among Transfer, Drift and Geostationary Orbits

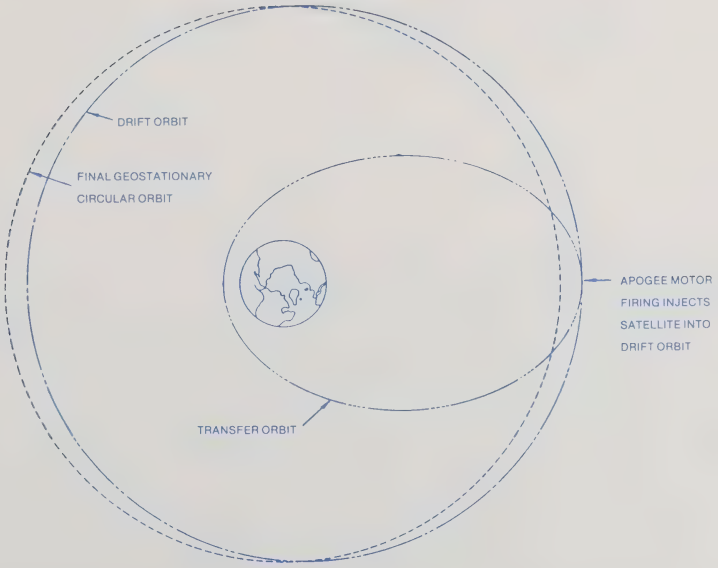


Figure 3.2 Typical Satellite Motion

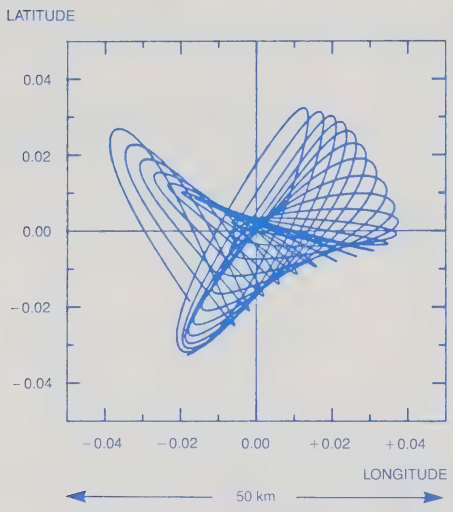


Figure 3.3 Typical Monthly Attitude Errors

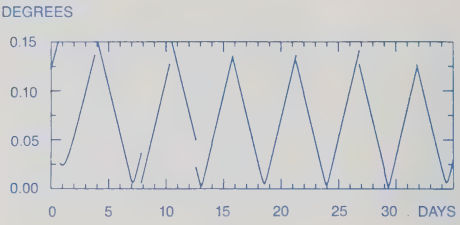
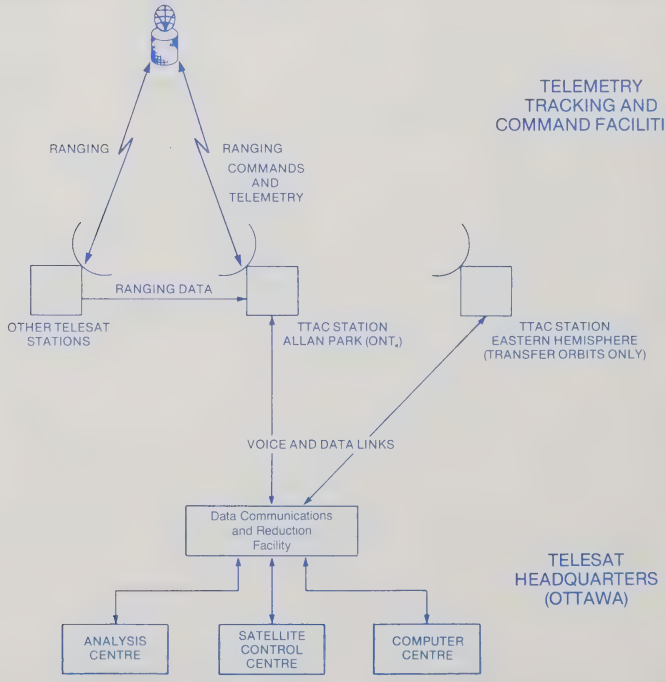


Table 3.1 Station Keeping Tolerances

SATELLITE	INCLINATION	LONGITUDE	ATTITUDE
ANIK A	± 0.10°	± 0.10°	0.15°
ANIK B	± 0.05°	± 0.05°	—
ANIK C	± 0.05°	± 0.05°	0.15°
ANIK D	± 0.05°	± 0.05°	0.15

Figure 3.4 Satellite Control System



The Satellite Control Centre (SCC)

This centre contains the consoles and status displays used by mission personnel during launch and transfer orbit activities, and by Operations personnel during normal operations. All relevant satellite data is displayed in this centre to assist in making decisions affecting the operation and control of the satellites and ground systems. Figure 3.5 is a photograph of the SCC. The main equipment elements in the centre and their functions are:

a) control consoles which house the master control panels for the intercommunications system, telephone links to the TTAC stations and other outside facilities, arrays of switches for updating satellite displays, and television monitors for the display of satellite telemetry data in engineering units, and in analog form, in essentially real-time;
b) status display boards for the display of the condition of all switchable functions in the satellites and other system parameters as required;
c) digital clocks for display of elapsed time and GMT; and
d) console terminals for remotely commanding the satellites and for controlling certain aspects of the computer system.

The SCC also contains a data communications and reduction facility which is visible beyond the SCC in Figure 3.5. All data from the tracking stations is received here for distribution to the Satellite Control Centre, the Computer Centre and the Analysis Centre.

The Analysis Centre (AC)

This centre houses the facilities required for all mission analysis activities during mission periods and station-keeping. It contains remote telemetry displays, an intercom station, digital clocks, interactive computer terminals and several electronic calculators.

The Analysis Centre is used to plan and monitor manoeuvres, determine the orbital elements and satellite attitude, and generate data predictions for the Satellite Control Centre and TTAC stations.

The Computer System (CC)

This centre houses the central portion of the Telesat computer network. In addition to communicating with tracking stations, the Computer Centre stores all historical telemetry and tracking data. The mission software system is kept on mini-computers located here. A more detailed description of the computer system is given later.

Figure 3.5 The Satellite Control Centre

Tracking, Telemetry and Command Facilities

These facilities include the Tracking, Telemetry and Command station (co-located with the earth station at Allan Park, Ont.), the antenna at the Lake Cowichan (BC) earth station, Telemetry and Command stations at Huggett (Alta.) and Terre Haute (Ind.) and, for transfer orbits only, Eastern Hemisphere TTAC station(s) (EHTS) outside Canada.

Computer controlled Ground Control Equipment (GCE) interfaces between the antennas and the data link to the Satellite Control Centre. A table of characteristics of the antennas is given in Table 3.2.

Table 3.2 TT & C Station Antenna Detail

	TT&C	HEAVY ROUTE	TAC 2	TAC 3	PILOT CONTROL FACILITY +	KTAC	STAC
Reflector Dia. (m)	11.0	30.0	8.0	4.6	3.7	4.5	4.5
Feed	Cassegrain	Cassegrain	Gregorian	Prime Focus	Cassegrain	Cassegrain	Cassegrain
G/T (dB/K)	6/4 GHz 28.0 14.12 GHz 34.0	37.5	20.5	17.0	NA	26.0	26.0
EIRP (dBW)	86 91	81	65	58	53	81	71
Tracking Mode	Autotrack	Steptrack	Manual	Remotely Steerable	Manual	Manual	Manual
Azimuth Range	± 270° From South	360	± 20 *	± 20 *	± 20 *	± 20 *	± 20 *
Elevation Range	0°-92°	0-90	± 10 *	± 10 *	± 10 *	± 20 *	± 20 *

* With Reference to the Angle of its Satellite
\+ Back Up for Anik A3 Only

Tracking Telemetry and Command Station (Allan Park)

This station consists of the TTAC antenna, the Heavy Route antenna, two Telemetry and Command antennas at 6/4 GHz, two Telemetry and Command antennas at 14/12 GHz, a Pilot Control Facility, and the associated GCE, computers, controls and displays (Figure 3.6).

Tracking, Telemetry and Command Antenna (TTAC)

This antenna is fully tracking (Figure 3.7), and is used during transfer and drift orbits. It also provides azimuth, elevation and range to all on-station satellites for orbit determination and is used for engineering tests of satellite performance. The RF equipment is redundant in 6/4 GHz and 14/12 GHz bands and is capable of operating on any channel on any Anik satellite.

Heavy Route Antenna (HR)

This antenna is fully tracking (Figure 3.8) and, for TT&C functions at 6/4 GHz, has two fully dedicated, automatically switched, transmit chains and a single non-redundant telemetry receive chain.

A third standby transmitter, shared by message traffic, is also available on demand. Fault signals from the HR command transmit systems are connected to the TTAC antenna which, under operation control (in the Beacon interlock Mode) can be set up as an automatic command backup. This antenna carries traffic to the primary 6/4 GHz satellite and is also equipped to provide antenna pointing and range measurements. In support of TTAC for Anik D, a frequency re-use (dual polarization) facility has been added.

Telemetry and Command Antennas (TAC)

The pilot signals for spinning Anik satellites are transmitted from the Allan Park earth station. For this purpose there are one fixed and one steerable 6/4 GHz antenna and two 14/12 GHz fixed antennas each dedicated to one satellite location. Each has a fully redundant, automatically switched, command pilot transmitter system and a single, non-redundant, telemetry receive chain. The RF equipment for both 6/4 GHz antennas is housed in a shelter under the TAC 2 antenna. The 14/12 GHz RF equipment is housed in a separate building which also contains power distribution systems. (Figure 3.9).

Figure 3.6 Tracking Telemetry and Command Station (Allan Park)

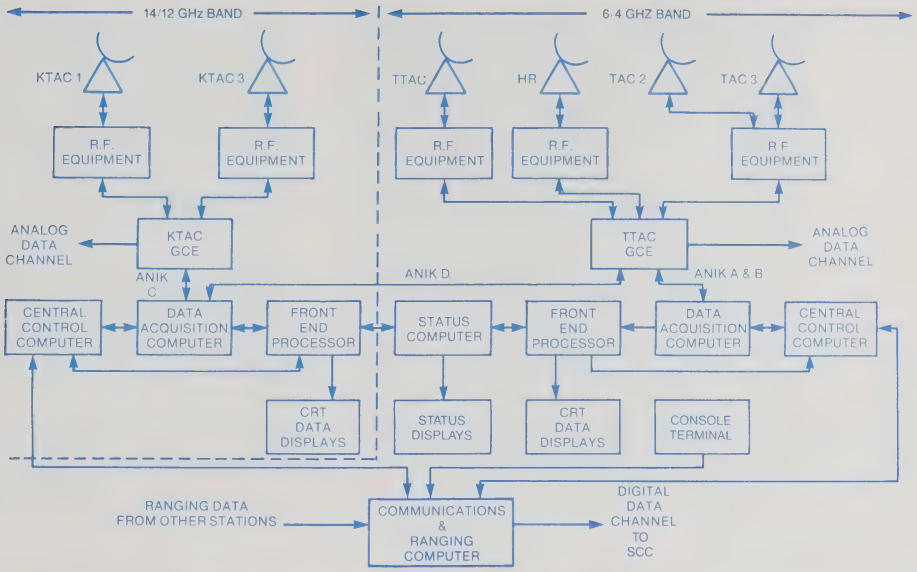


Figure 3.7 TT&C Antenna

Figure 3.8 A Heavy Route Antenna

Figure 3.9 Telemetry and Command Antennas

6/4 GHz Band

14/12 GHz Band

For an Anik C satellite antenna tilted South, to give better coverage of the continental USA, a Southern Pilot and Telemetry and Command Station (STAC) is required south of the Canadian/USA border. If the satellite antenna were tilted North, a pilot and command station would be required further north.

No new station would be required if Anik D satellite antennas were tilted south for US coverage.

Ground Control Equipment (GCE)

The ground control equipment processes the telemetry, command, and ranging signals required to control and monitor all satellite on-board functions. Two incoming telemetry data streams are decoded for each satellite to provide digital information to the Data Acquisition Computer (DAC). These consist of voltage, current, temperature and propellant pressure readouts and pulses representing sun and earth positions relative to the satellite. One outgoing command data stream for each satellite, encoded by digital inputs from the Data Acquisition Computer, is transmitted on baseband control tones to the satellite. The commands perform a series of switching functions, including thruster operation, battery switching, telemetry data stream selection, and transponder switching.

Range is determined by transponding four audio tones on the RF carrier. The phase delays between each transmitted and received tone are measured, converted to propagation delays and, ultimately, range. The highest frequency tone provides the required accuracy and the three lower tones are for ambiguity resolution. In addition to the usual command functions, the Anik A, C and D command subsystems also provide pilot signals for despin and pointing control of the satellite communications antennas. The high reliability requirement, placed on the command transmission system by the pilot signal, is achieved by dual uplink chains with automatic switch-over from one chain to the other.

Other Satellite Control Stations

Lake Cowichan Antenna

This is a 6/4 GHz 10 m antenna and in addition to its traffic facilities it is equipped for ranging and the data is transmitted to Allan Park over the satellite order wire system. The ranging facility is to be relocated to Huggett (Alta.) in 1984.

Huggett Antennas (KTAC) and Terre Haute Antennas (STAC)

These are similar to the 14/12 GHz TAC antenna at Allan Park. They are equipped for ranging and the data is transmitted to Allan Park over leased lines.

Eastern Hemisphere Tracking Station (EHTS)

This station is required only during the transfer orbit phase of the mission, when the satellite is not visible from Allan Park. It is leased from a few weeks before launch to Apogee Motor Firing. The station acquires the satellite about one hour after lift-off, and provides tracking data for prediction programs which are used to provide acquisition data for the Allan Park TTAC antenna. The Eastern Hemisphere tracking station also monitors the status of the spacecraft, and can transmit commands.

For the Anik A, C and D series of satellites a station was located on Guam, an American Island Territory in the Western Pacific (Figure 3.10). It has been upgraded with an interchangeable feed system to allow operation in both 6/4 and 14/12 GHz bands. For Anik B, one station was located at Carnarvon in Western Australia and one at Fucino in Italy.

Figure 3.10 Eastern Hemisphere Tracking Station (Guam)

The Computer System

The Telesat computer system consists of a series of mini-computers located at each of the tracking stations and at the Computer Centre in Ottawa.

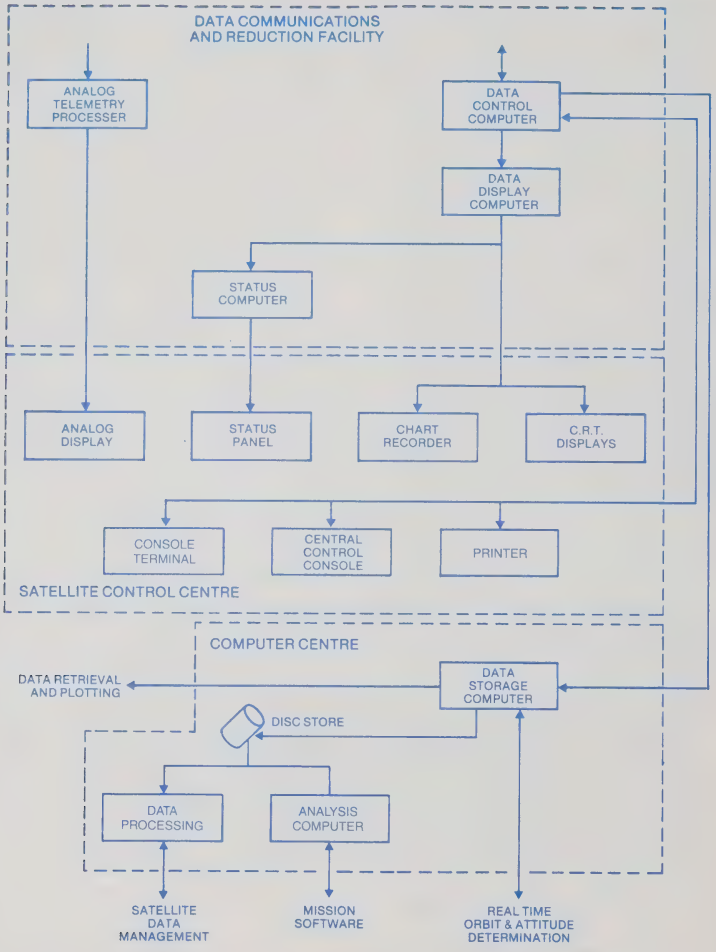
Allan Park Computer System

The Data Acquisition Computers (DAC) at Allan Park (Figure 3.6) control all telemetry, command and ranging equipment and the resulting data is routed to the Front End Processors (FEP) and the Central Control Computers (CCC). The FEPs scale and average all telemetry data and convert it to engineering units for local CRT display at Allan Park. This processed data is passed to the CCC for transmission to Ottawa over the digital modem data channel.

Satellite commands, from the Satellite Control Centre, are received over the data line by the CCC. This computer controls commanding and passes command data to the DAC for transmission through the GCE to the spacecraft. A local console terminal may be used to execute satellite commands in the unlikely event that the Ottawa-Allan Park links are all out of service.

Anik B spacecraft command and telemetry information is sent by the FEP to a status computer which updates the spacecraft status displays.

Figure 3.11 Ottawa Computer Facilities



Ottawa Computer Facilities

Data transmission to and from the tracking station is controlled by the Data Control Computer (DCC). All operations at this level are in real-time (Figure 3.11). During a launch mission, the Eastern Hemisphere station interfaces with the DCC through the EHTS interface computer.

The satellite controller initiates satellite commanding and data collection for all satellites through the console terminal, connected to the DCC.

The DCC passes data to the Data Display Computers (DDC) which update the chart recorders, status and CRT data displays in the Satellite Control Centre, where it is monitored by the satellite controller. Data from the DCC is also routed to a data storage computer (DSC) which stores all data on disc or magnetic tape for use by other programs.

In addition to its data storage functions, the DSC also contains real-time orbit and attitude determination software. This processes incoming tracking and sensor data, and provides the orbit and attitude information used for satellite stationkeeping.

Telemetry data may also be retrieved through the DSC and plotted on a hard-copy terminal for the analysis of spacecraft performance.

Mission software and other computing jobs may be run in non-real time using the Analysis Computer (ANC), which has access to all data stored on disc. A number of backup computers are available at all times to ensure system reliability. These computers also perform various off-line simulation and test functions during software system design and development.

Mission Software System

The Mission Software System (MSS) is used by mission analysts to support all activities related to satellite dynamics. The system includes approximately forty computer programs as well as a number of magnetic disc files, and resides exclusively on HP 1000 F-series minicomputers located in the Computer Centre.

The MSS supports the following activities:

a) pre-flight mission planning;
b) real-time mission simulation;
c) transfer/drift orbit navigation and control;
d) post-flight mission analysis; and
e) stationkeeping.

In order to accomplish the above, the MSS is capable of predicting a wide range of information. This includes sensor and tracking data, as well as eclipse periods, proximity to other satellites, launch windows, etc.

The orbital elements and attitude parameters may be estimated during all mission phases using batch or Kalman filter methods. During the transfer orbit phase, analysts may use the real time Kalman filter to monitor the progress of spin-axis reorientations. On station, the orbit and attitude parameters of up to six satellites may be estimated in real-time, requiring minimum intervention from analysts.

The MSS may be used to plan the following types of manoeuvres.

a) large spin-axis reorientations;
b) apogee motor firing;
c) angular momentum adjustments;
d) drift orbit synchronization, and
e) stationkeeping attitude, drift, eccentricity and inclination manoeuvres.

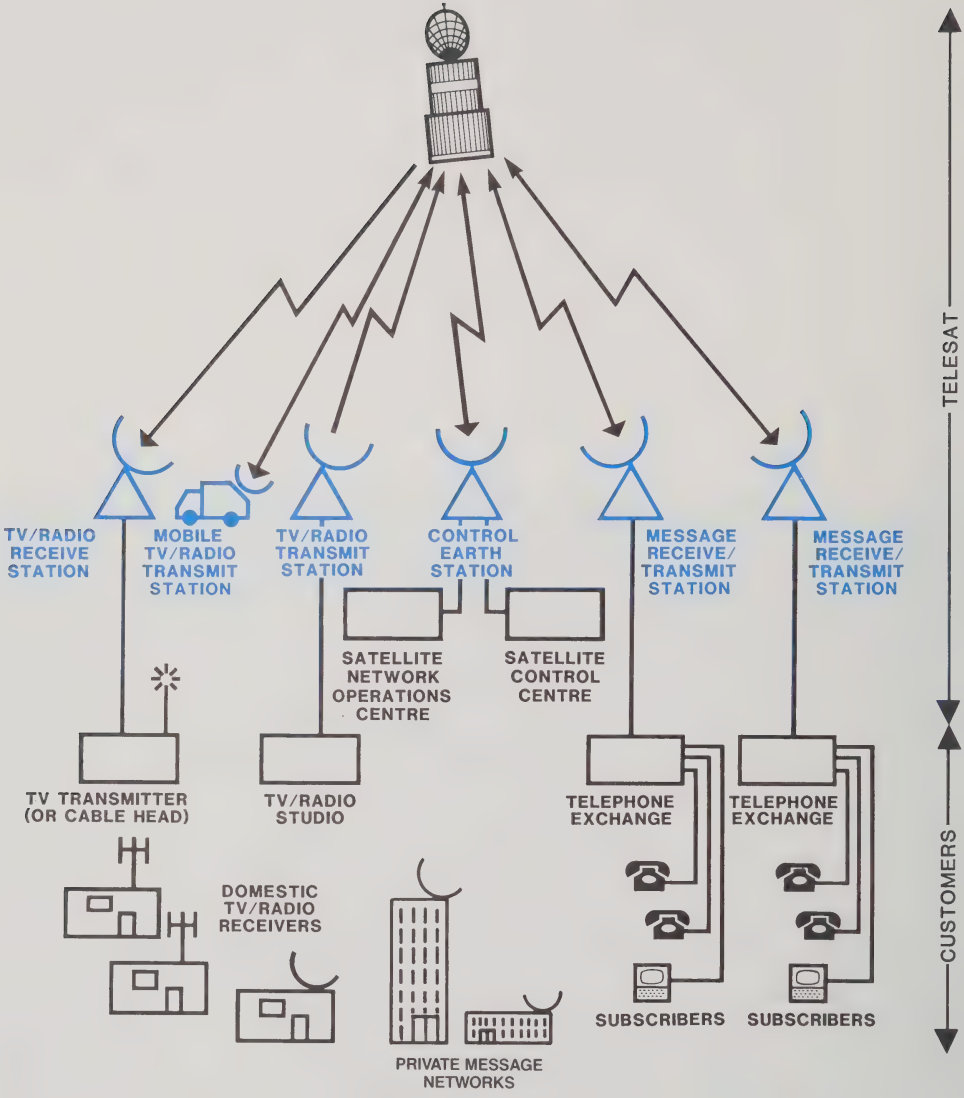
In addition to the above, the MSS contains a real-time mission simulator which is capable of introducing noised telemetry, attitude sensor and tracking data into the Data Acquisition System. This tool is used during mission simulations and rehearsals to exercise the Satellite Control System in a realistic manner.

Most of the software elements of the MSS fall into one of three categories:

a) executive programs which accept simple card inputs, and control the execution of one or more modules to complete a specific function such as orbit determination;
b) module programs which accept input from the executive programs and perform limited operations such as orbit propagation, tracking data error analysis, orbit improvement, etc. and;
c) interactive programs which accept input from a keyboard terminal, and are used to edit disc files, simulate or process data in real-time.

This structure permits software designers to standardize and minimimize inputs to the MSS, resulting in a system which is easy to use.

Chapter 4
Earth Station Facilities


TELESAT
CUSTOMERS
TV/RADIO RECEIVE STATION
MOBILE TV/RADIO TRANSMIT STATION
TV/RADIO TRANSMIT STATION
CONTROL EARTH STATION
MESSAGE RECEIVE/ TRANSMIT STATION
MESSAGE RECEIVE/ TRANSMIT STATION
SATELLITE NETWORK OPERATIONS CENTRE
SATELLITE CONTROL CENTRE
TV TRANSMITTER (OR CABLE HEAD)
TV/RADIO STUDIO
TELEPHONE EXCHANGE
TELEPHONE EXCHANGE
DOMESTIC TV/RADIO RECEIVERS
SUBSCRIBERS
SUBSCRIBERS
PRIVATE MESSAGE NETWORKS

Earth Station Facilities

4

Introduction

This chapter describes how the satellite RF channels can be used to carry traffic, and the design features required of the various types of earth station.

The free space loss over the distance between an earth station and the satellite is in the order of 200 dB and satellites in the Telesat system are spaced less than 5° apart. An earth station must therefore be designed to achieve the high gain necessary for transmission (uplinking) and reception (downlinking). The antenna must have the ability to focus the signal within a very narrow beam to minimize adjacent satellite interference. However, despite differences in detail, all earth stations comprise the same basic elements, as illustrated in Figure 4.1 for a redundant station.

Figure 4.2 shows the disposition of Telesat-owned earth stations in 1982.

Figure 4.1 Basic Elements of a Redundant Earth Station

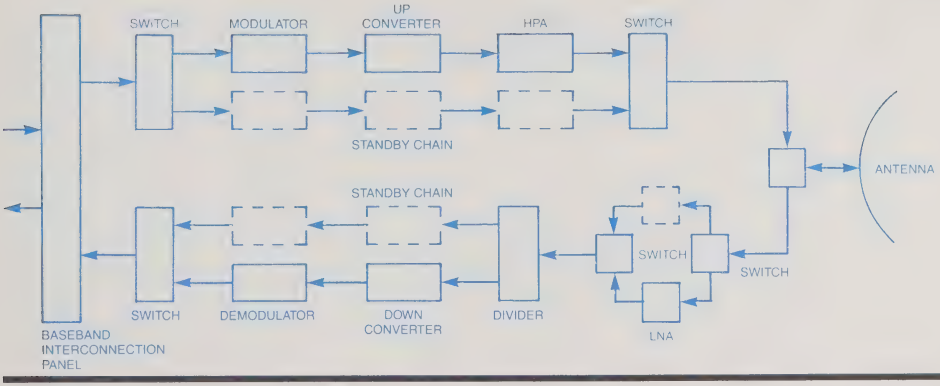
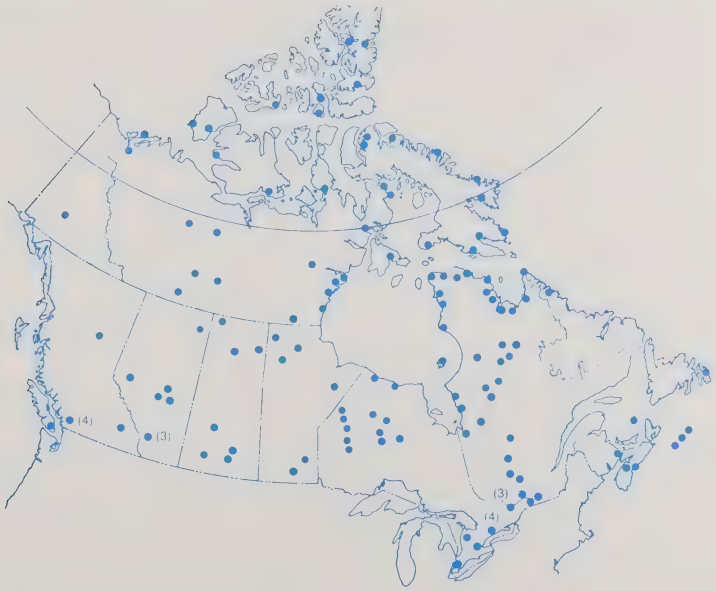


Figure 4.2 Earth Station Locations 1982



Station Site Selection

Stations operating with the Anik satellites are normally located within Canada unless specific exceptions are authorised. The essential requirements governing site selection are as follows:

— the proposed location must provide a clear line of sight towards the satellite.

— transmissions from the site at 6 GHz must not cause interference to existing radio systems. Transmissions at 14 GHz do not share a radio frequency band with terrestrial systems and present no problems.

— radio frequence interference (RFI), from other sources, at the site must be within acceptable limits.

— the site must be suitable for construction of the station.

Ideally an earth station location should provide an antenna elevation angle greater that 5° in order to minimize fading. However, since elevation angle is a function of latitude and the orbit location of the satellite, the elevation is predetermined for a given location. Most areas in Canada meet this criteria except for those in the extreme north (Figure 4.3).

Special Considerations

Environment

Most of Telesat's earth stations are in remote areas in the north of Canada where extremes of climate are the norm. Since electronic equipment works best within a limited temperature/humidity range, some form of environmental control is essential. This varies from a self-regulated, heater-blower, fan arrangement in a transportable message terminal, to full air conditioning in a large station. Most antennas have some form of de-icing equipment.

Foundations

Since the satellites are kept within strict position tolerances, most earth station antennas do not have to track. However, since the antennas have narrow beams, the pointing accuracy of fixed antennas must be kept within close limits. This is assured by the structural design of the antenna mount and foundation. For roof-top locations, the structural design of the building has to be evaluated. When the antenna is mounted at ground level, the foundations must be designed to suit the soil conditions. Frequently, soil investigations must be undertaken to determine the optimum type of foundation design. The antenna should also be sited as near as possible to the communications equipment to reduce losses in the connecting link.

Figure 4.3 Canada Showing 5° Elevation Angle to Synchronous Orbit

Earth Station Facilities — 6/4 GHz

Message Facilities

Telesat's message traffic can be divided into Heavy, Medium, and Thin (Light) Route. Figure 4.4 shows the 1982 network of message earth stations, and Table 4.1 summarizes their main features.

Heavy Route Message Facilities

Each channel of a 6/4 GHz satellite is capable of carrying over 960 one-way multiplexed voice circuits using frequency modulated, single access, carriers (Figure 4.5). Heavy Route message stations have 30 m diameter antennas which, with a parametric amplifier, provide a minimum G/T of 37.5 dB/K and a voice circuit noise performance of 37.5 dBrnc0. The 30 m antennas incorporate a wheel and track type mount to provide rotation in azimuth (340°) and an arc and pinion to provide elevation adjustment (90°). The simplified elevation/azimuth tracking system maximizes the received signal by moving the antenna through discrete steps. The antennas are equipped with automatic ice detectors which alert the station staff to the possibility of signal degradation. An elevated equipment room, mounted near the antenna elevation axis, houses the high power amplifiers (HPAs) and the low noise amplifiers (LNAs). The antenna pedestal is connected to the main building by a covered passageway.

The remainder of the message equipment including hot standby chains, (excluding the hot HPAs and LNAs), control consoles and power equipment are housed in the main building .

Commercial power is provided through an uninterruptible power supply incorporating a rotary converter, diesel and turbine generators and a battery bank with fifteen minutes capacity. If the commercial power fails the batteries carry the load until the generators (which start automatically) are up to speed. Figure 4.6 shows the main earth station located at Allan Park (Ont.).

Table 4.1 Earth Station Characteristics – Message Facilities at 6/4 GHz

TRAFFIC		ANTENNA DIAMETER (m)	G/T (dB/K)	QUALITY	POWER BACK UP	REDUNDANCY
Heavy Route		30	37.5	37.5 dBrncO	Batteries & Generator	Yes
Medium Route FM/FDMA	a	30	37.5	37.5 dBrncO	Batteries & Generator	Yes
	b	10	28	44.0 dBrncO	Batteries & Generator	Yes
	c	8	27.5	44.0 dBrncO	Batteries & Generator	Yes
PCM/TDMA	a	30	37.5	34 dBrncO	Batteries & Generator	Yes
	b	10	31	34 dBrncO	Batteries & Generator	Yes
Thin Route Message	a	30	37.5		Batteries & Generator	Yes
	b	10	28	Idle Noise 37.5 dBrncO max.	Customer Provided	Yes
	c	8	26		Batteries	Yes
	d	4	22		Batteries	Yes
	e	4.5	21		Batteries	Yes
Transportable	a	3.6	19		Batteries	Can be provided
	b	3.6	19		No	No
Light Route TDMA		4.5	22	Idle Noise 35 dBrncO max.	No	No

Medium Route Message Facilities

FREQUENCY DIVISION MULTIPLE ACCESS (FDMA)

Each channel of a satellite is capable of operating in a multiple access mode using frequency division multiple access (FDMA) techniques. In this case, the number of voice circuits per carrier is a function of the number of carriers, the type of modulation and the G/T of the accessing earth stations. For example, five carriers could support at least 168 two-way analogue voice circuits between one earth station having a G/T of 37.5 dB/K and four other earth stations having a G/T of 28 dB/K (Figure 4.7).

Allan Park is the hub earth station in a four-carrier Medium Route Message Network using a partial satellite channel. Two other stations in this network have remotely steerable, non tracking, 10 m antennas and parametric amplifiers giving a G/T of 28 dB/K. The fourth station has an 8 m fixed antenna and a G/T of 27.5 dB/K.

At each of the three remote stations, all the communication and power equipment is in a building located close to the base of the antenna and hot standby chains are included. Commercial power is provided through an

Figure 4.4 6/4 GHz Message Service Locations 1982

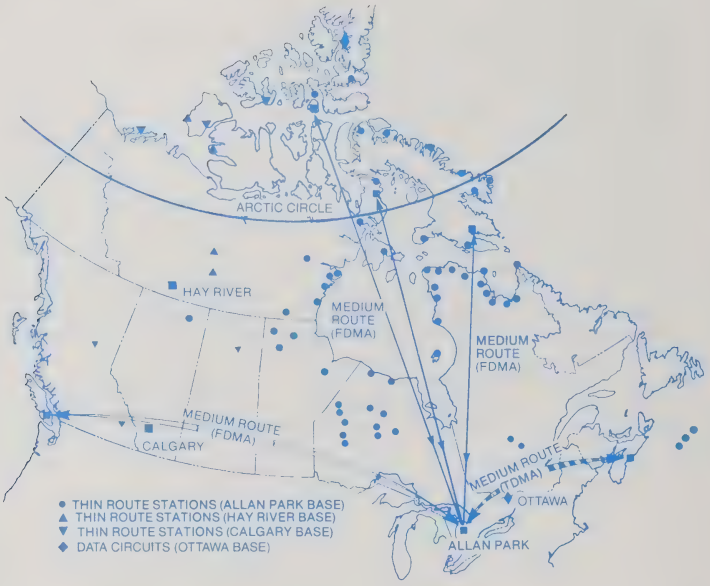


Figure 4.5 Heavy Route Message Traffic (Frequency Modulation — Single Access)

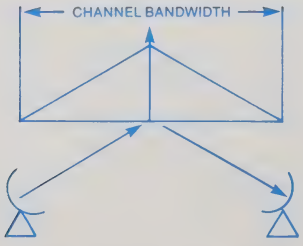


Figure 4.6 Main Earth Station — Allan Park

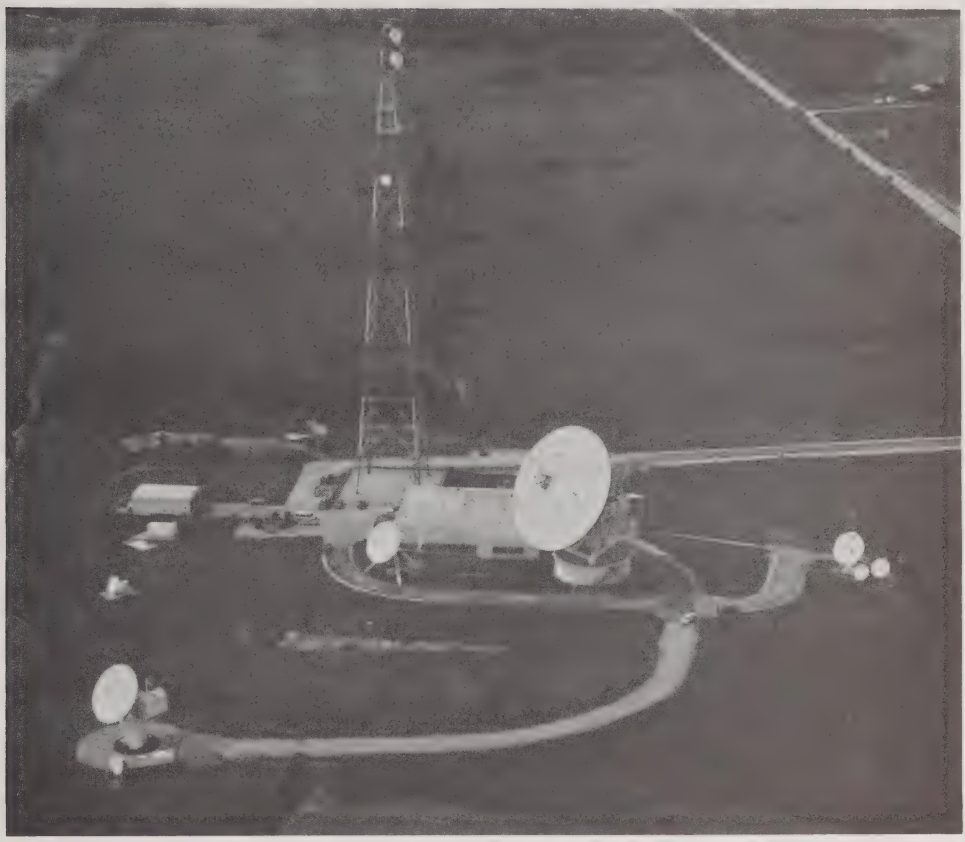


Figure 4.7 Medium Route Message Traffic (Frequency Division Multiple Access (FM/FDMA)

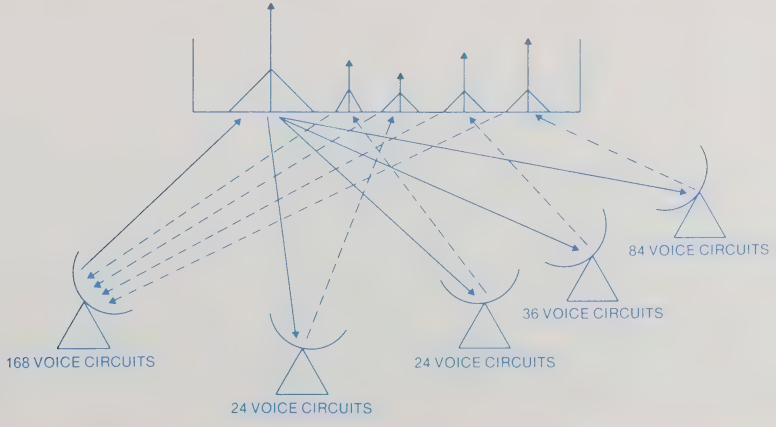


Figure 4.8 Medium Route Station

uninterruptible power supply consisting of a static inverter, a diesel generator which starts automatically in the event of commercial power failure, and batteries with four-hour capacity. Figure 4.8 shows a typical Medium Route Earth Station.

TIME DIVISION MULTIPLE ACCESS (TDMA)

As an alternative to dividing a satellite channel into discrete carriers spread in frequency, it is possible to allow access, by two or more stations, to the whole channel on a time division basis (Figure 4.9). Telesat used this method to provide 300 two-way circuits between two stations. One station was one of the Heavy Route stations described above, and the other had a 10 m antenna and a parametric amplifier which gave a G/T of 31 dB/K.

Thin Route Message Facilities

SINGLE CHANNEL PER CARRIER

Another FDMA method of dividing a satellite channel is by the single channel per carrier (SCPC/FDMA) technique. In this case each voice circuit modulates an RF carrier, using two or four phase shift keying (PSK) with delta coding, and up to 360 two-way circuits can be carried by one satellite channel (Figure 4.10).

In the Telesat system the carriers are on preassigned frequencies and several telephone circuits can be carried from a remote location, via a main earth station (e.g. Allan Park), to the Canadian telephone system. Voice activation is used on the carriers to increase the system capacity and most of the baseband equipment is designed to allow upgrading, to demand assignment, for further flexibility and capacity. Circuits can be provided to carry data at 2400 b/s, or four teletype channels at rates up to 110 baud, simultaneously with the voice service. Other data rates can be made available.

The original Thin Route Message stations had fixed 8 m antennas with a GT /of 26 dB/K, or 22 dB/K. Newer stations have 4.6 m antennas and a G/T of 19.5 or 21 dB/K. All antennas have sub-reflector and feed horn de-icing. At some locations the LNA is housed on the antenna in an environmentally controlled enclosure.

The communications equipment is housed in a small building, or on the customer's premises, near the antenna. The simplest stations have single, non-redundant, receive and transmit chains, but larger ones have some form of redundancy to improve availability. Power from local commercial sources is conditioned on site and some stations have batteries with approximately four-hour capacity for automatic use in the event of a power failure. Figure 4.11 shows a typical Thin Route station.

Figure 4.9 Medium Route Message Traffic (Time Division Multiple Access — TDMA)

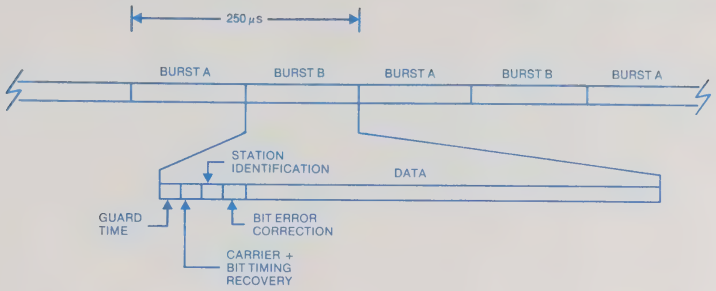


Figure 4.10 Thin Route Message Traffic (Single Channel Per Carrier SCPC/FDMA)

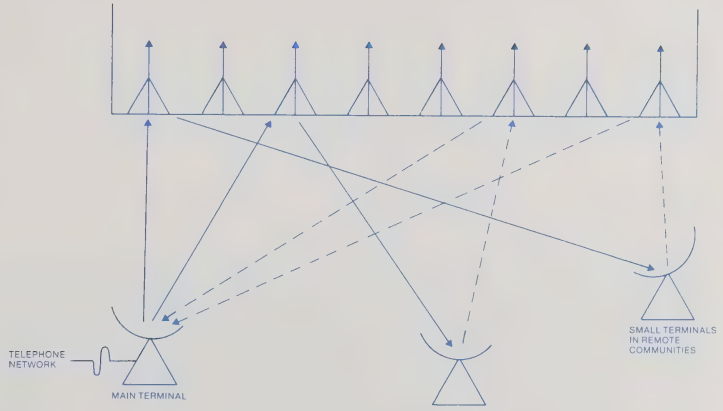


Figure 4.11 Thin Route Station

TRANSPORTABLE MESSAGE SERVICE

Two types of Transportable Message Station are available for use on short notice, or for short periods. One is basically a two circuit Thin Route SCPC station, with a 3.6 m antenna and a small shelter, designed for air transportation (as one load) in aircraft such as the Twin Otter. Once on site the station can be erected and in service in a few hours. The other is a single channel Thin Route Station with a 3.6 m antenna and a desktop electronics package which is installed on the customer's premises. Figure 4.12 shows such a station.

LIGHT ROUTE TDMA

A Light Route TDMA system, with a lower bit rate than the Medium Density TDMA service, uses only a small portion of the power and bandwidth of a satellite channel.

The LR TDMA system is expected to be an economical means of providing a variety of services to the business community. In order to promote interest by both the end users and the telephone companies, Telesat has procured four LR TDMA earth stations to be used for customer demonstrations and service trials which started in 1983. These will be located on customer's premises but, for small users, shared earth stations can be used in connection with terrestrial telephone systems.

The stations will allow networks to be set up with a mixture of low speed data, high speed data, facsimile, voice, audio conferencing and video conferencing circuits. Since the system is basically software controlled, it is very easy to add new terminal devices, change the data rate of the uplinks or even add new stations to the network. In addition there is a great deal of status information provided, to both the user and the network controller, as an aid in network management and in fault identification and repair.

FAR NORTH SERVICE (EUREKA)

Because of the high latitude, (80° N) the elevation angle towards an Anik satellite from Eureka is less than 1°. This is substantially below the normally accepted lower limit of 5° This location experiences severe atmospheric fading, during the summer, compared with locations with higher elevation angles. In order to operate with practicable fade margins, two earth stations, separated by about 1.5 km, are used in a space diversity system.

Figure 4.12 Transportable Message Station

Television and Radio Facilities

One satellite channel can carry one colour television video FM signal with associated program audio circuits and a cue and control circuit on subcarriers, plus two separate radio program carriers (Figure 4.13). Such a channel can also be used for teleconferences. The cue and control circuit is used to order those stations so equipped to switch transmitters ON/OFF or to select transmit and receive channels. The map at Figure 4.14 shows the location of Telesat's Television and Radio Earth Stations in 1982.

A wide variety of audio services, such as mono or stereo radio programming, and data can be offered with a basic video service. This would use a combination of standard (high level) and companded (low level) audio subcarriers combined with the video signal. The low level audio subcarriers can provide high quality 15 kHz circuits for a variety of applications. Typically one high level and up to eight low level subcarriers are being considered.

Scrambling of video signals for security is a reality at 6/4 GHz for one customer. It is expected that scrambled video will become more common in the near future.

Table 4.2 summarizes the main features of the 6/4 GHz television and radio earth stations.

Figure 4.13 6/4 GHz Television/Radio Channel

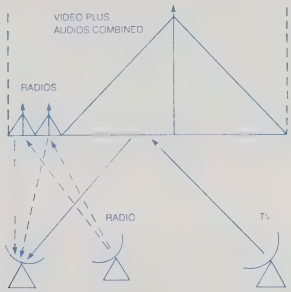
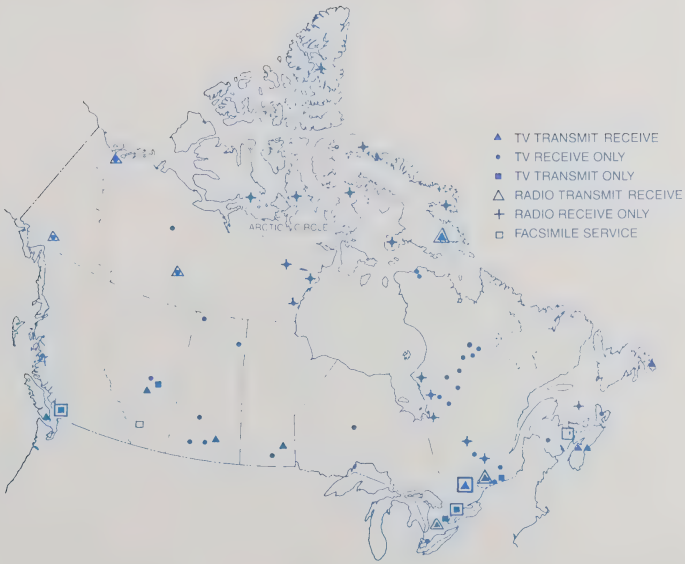


Figure 4.14 6/4 GHz Television & Radio Service Locations 1982



Transmit and Receive Television Facilities

The Heavy Route stations are equipped to transmit and receive TV programs as are six Network Television stations (NTV). The latter have antennas, G/T, power back up and buildings similar to those for the Medium Route Message Service. The receive and transmit chains can operate on any one of a set number of frequencies (frequency agile).

The video signal-to-noise ratio at these stations is 54 dB or better. The NTV stations provide regional distribution of 'Network' grade TV in and out of provincial capitals or major centres. Figure 4.15 shows a typical NTV station.

Transmit Only Television Facilities

These stations provide television signals to remote communities for local distribution by cable. They have 8 m or 11 m antennas and provide a signal to noise ratio, into a small receiving antenna, of at least 45 dB. They have no redundancy and the customer provides any power back up.

Receive Only Television Facilities

REMOTE TELEVISION STATIONS (RTV)

These stations receive television signals in remote communities for rebroadcast from a low power VHF TV transmitter. They are equipped with an 8m (26 or 22 dB/K), or a 4.5 m (21.5 dB/K), fixed antenna and a building which houses the communications equipment. In either case a video signal-to-noise ratio better than 48 dB is achieved. At some locations the LNA is in an environmentally controlled enclosure on the antenna.

Most of the stations have a single non-redundant receive chain and some have frequency agility for use with the cue and control signal. Power is supplied from a local commercial source and some stations have up to eight hours of battery back-up. Figure 4.16 shows a typical RTV station.

Table 4.2 Earth Station Characteristics — Television & Radio Facilities at 6/4 GHz

TRAFFIC	ANTENNA DIAMETER (m)	G/T (dB/K)	QUALITY	POWER BACK UP	REDUNDANCY
Network TV (Transmit/Receive)	a 30 b 10	37.5 28	54 dB Video S/N	Batteries & Generator	Yes Yes
Northern TV (Transmit only)	a 11 b 8	NA NA	Min 45 dB Video S/N	Customer Provided	No No
Remote TV (Receive Only)	a 8 b 8 c 4.5	26 22 21.5	48 dB Video S/N	Some Have Batteries	Some Have
Frontier TV (Receive Only)	a 4.5 B 3.6	18.5 18.5	45 dB Video S/N	No No	No No
Transportable TV (Transmit/Receive)	a 4.5 b 4.5	NA NA	48 dB Video S/N	Generator No	Yes No
Facsimile Transmit Receive	 8.0 4.5	 NA 21.5	Better than 85 line screen	 No No	 No No

Figure 4.15 A Network Television Station

Figure 4.16 Remote Television Station

FRONTIER TV STATIONS (FTV)

These stations are a lower cost version of the RTV and provide a slightly lower quality of service by using overdeviation — i.e. a narrower IF bandwidth to improve threshold margin. They are equipped with a single video channel (fixed frequency) receiver, or more than one video channel (for frequency agility) with manual or remote switching. The narrower bandwidth receiver is typically a self-contained equipment shelf, mains powered, that is housed on the customer's premises.

They have a 4.5 m, or a 3.7 m, fixed antenna and give a G/T of 18.5 dB/K or better, and do not have any power back-up. FTVs are normally found at cable head ends, remote mining camps or small communities where maintenance is accomplished in general by replacement of the whole receiver. Similar stations are also used to provide programs to cable operators in major cities. Figure 4.17 shows a typical FTV station.

Cue and Control Service

Control centres in Toronto and Montreal have remote control of the transmission and reception of programs at those TV stations that have Cue and Control equipment.

Transportable TV Service

Transportable TV stations are used to provide TV transmissions for short periods of time either from an existing station, not equipped for TV transmission, or from locations where no station exists. In the first case, only those items of electronic equipment needed are shipped and installed. In the second case, complete road transportable TV stations with various capabilities are available.

One station is a trailer which carriers a self-contained diesel electric power generator, two complete uplinks to operate on any one of twelve satellite channels, a frequency agile TV receiver (twelve channels) and monitoring equipment. The second station is a truck with the equipment installed in pre-packaged racks that can be removed for air transportation if required. This configuration accommodates a single video uplink chain only.

Two 4.5 m antennas are available which, when used in conjunction with 400 W power amplifiers, provide a signal to noise ratio at the Heavy Route and Network Television stations in excess of 48 dB.

One of the antennas can be air transported if required. The second antenna is installed on a trailer and can be hydraulically erected, and operational, in less than twenty minutes (Figure 4.18). Both can be operated with either of the electronic equipment packages discusssed above.

In all cases, careful site selection is needed to provide an Radio Frequency Interference (RFI) free location, having a line of sight to the satellite, at a short cable distance from the customer's equipment, and a power outlet. Once on site, these stations can be in service within one to three days depending on the antenna type and size.

Figure 4.17 Frontier Television Station

Radio Service

Some RTV stations have had equipment added to provide a capability for transmission and reception, or for reception only, of SCPC radio programs. This service is independant of any television transmissions.

Facsimile Facilities

The transmission of a daily newspaper, by high speed facsimile, started in November 1980 over a satellite link from a centre city head office to printing plants in other cities. The transmitting station has an 8 m antenna and the receiving stations 4.5 m. A full transponder is used for this service which allows a complete newspaper to be transmitted in about 50 minutes.

Experimental Techniques

Data Broadcast

Studies and experiments are underway of broadcasting data from banks, stock markets, weather offices etc. via one central station to many small receiving stations (0.6 m antennas). This could be wide band, using code division multiplex digital techniques, and having full Canada coverage.

Digital Radio Programs

Also under consideration are applications of digital SCPC techniques to provide very high quality program circuits. These would perhaps be compatible with new digital recording and playback equipment. The use of two carriers would allow transmission of stereo radio programs.

Figure 4.18 Transportable Television Station

Earth Station Facilities — 14/12 GHz

Table 4.3 summarizes the main features of the major 14/12 GHz earth stations and Figure 4.19 shows their locations.

Figure 4.19 14/12 GHz Service Locations

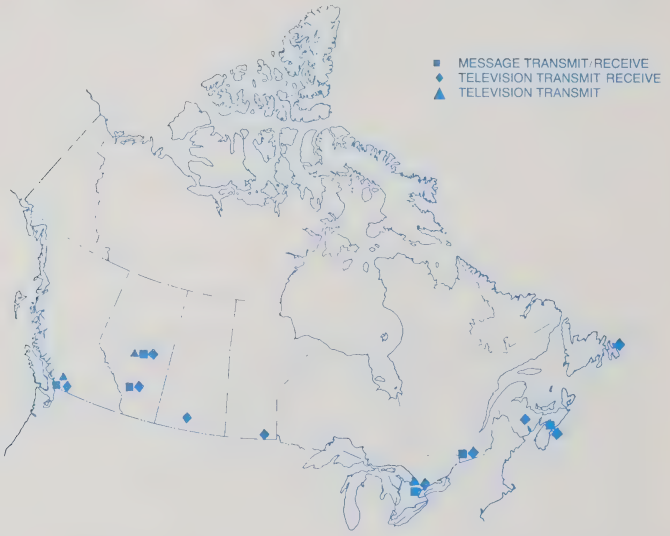


Table 4.3 Earth Station Characteristics — 14/12 GHz Facilities

TRAFFIC		ANTENNA DIAMETER (m)	G/T (dB/K)	QUALITY	POWER BACK UP	REDUNDANCY
Digital Message and TDMA		8	35	BER 10^{-7}	Customer Provided	Yes
SCPC Voice/Data (In Planning Stages)	a	1.8	19.5	49.0 dB Voice TT/N		
	b	2.5	22.0	Companded		
Remote				BER 10^{-6}		
	c	3.0	24.0	Low Speed Data	Yes	As Required
Central	a	4.5	28.0	BER 10^{-7}		
	b	8.0	33.0	High Speed Data	Yes	Yes
Television	a	8	35	48-54 dB Video S/N	Customer Provided	Yes
	b	8	29.5			
	c	4.5	26.5	46-52 dB Video S/N	As Required	As Required
Television Receive Only	a	1.8	16.5	40-42 dB Video S/N	No	No
	b	1.2	13	42 dB Video S/N (Typical)	No	No
Transportable TV						
Transmit		1.8	N/A	43 dB Video S/N	Generator	No
Transmit/Receive		3.7	25			

Figure 4.20 14/12 GHz Earth Station (on a customer's building)

Message Facilities

Each channel of an Anik C (14/12 GHz) satellite can carry two DS-3 bit streams at a composite rate of 91 Mb/s using four phase QPSK modulation. The earth stations associated with this traffic have 8 m diameter antennas, and 130 K parametric amplifiers, to give a G/T of 35 dB/K. These antennas incorporate a step-track drive system controlled either manually or by a tracking receiver. Full de-icing equipment is provided.

Since there is little terrestrial radio interference at 14/12 GHz, the antennas can be located in the centre of cities, either on the ground or on top of buildings (for example, one antenna is 80 m above ground level). Each LNA is in an environmentally controlled enclosure on the antenna mount and the remainder of the electronics equipment is in a nearby shelter. The shelter is close to the switching centre of a telephone company. (Figure 4.20)

Integrated Satellite Business Network (ISBN)

(Stratoroute 2000)

Using the broadband digital facilities of an Anik C satellite, this service will allow business customers to integrate their voice and data communications. The initial system, starting in mid 1984, will use TDMA at 30 Mb/s between three common user earth stations integrated with terrestrial networks. The bit rate will increase to 45 Mb/s in 1985. The service will be available in 100 kb/s blocks and, within their allocated capacity, customers will be able to set up, and change, their own dedicated communications networks. This TDMA system is controlled from a computer based Network Management Control System (NMCS). Each customer will have his own terminal accessing the NMCS for requesting service and receiving status and usage reports. (Figure 4.21).

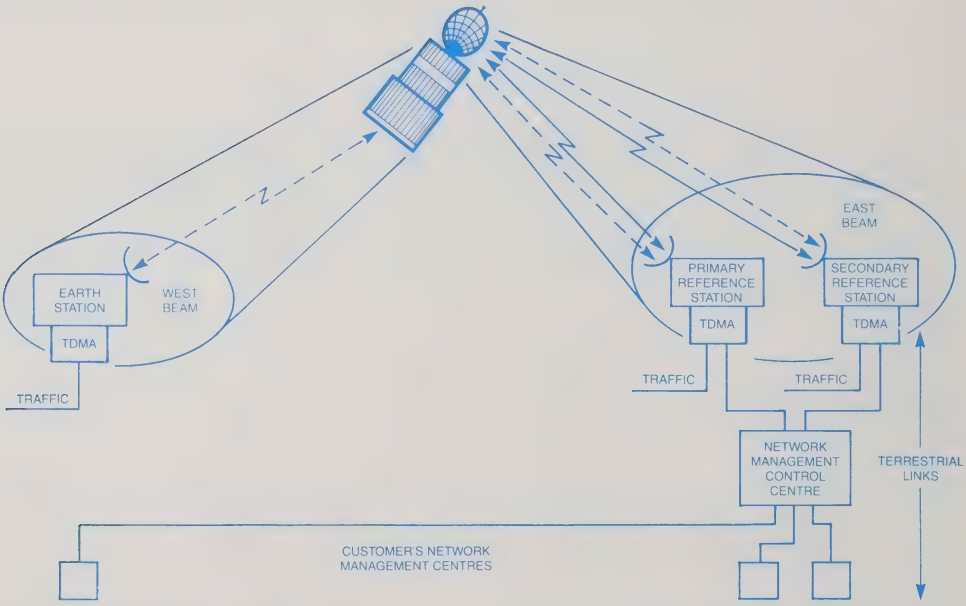
In future, if required, 4.5 m earth stations could be located on a customer's premises.

Television and Radio Facilities

Each channel of an Anik C (14/12 GHz) satellite can carry two television video signals, and associated 15 kHz audio circuits, on subcarriers. As with the 6/4 GHz television channels, teleconferencing can also be provided. A wide variety of other audio services can be offered with a basic video service using the companded (low level) subcarrier technology. Typically one high level and up to five low level subcarriers are being considered for 14/12 GHz applications. Studies are underway to evaluate the feasibility of adding digital SCPC radio to the video channels as has been done at 6/4 GHz.

The earth stations carrying digital message traffic are also equipped to carry television. The station at Montreal entered service in September 1980, to distribute television programs to earth stations in Quebec, using Anik B.

Figure 4.21 ISBN Initial System



Some video only sites have 8 m antennas, and FET LNAs, to give a G/T of 29.5 dB/K. For other TV services, a 4.5 m antenna is used which, with a FET LNA, gives a G/T of 26.5 dB/K and such stations entered service in February 1983 (Figure 4.22).

Digital Television Conferencing

Two way video, plus audio, 1.5 Mb/s digital television conferencing is planned for mid 1984. Spare capacity on the Integrated Satellite Business Network would be used in conjunction with terrestrial networks. The 1.5 Mbps video codecs will be located at the Central Office nearest to the ISBN Earth Station.

Transportable TV Service

A transportable television uplink on one motorized vehicle, with order wire equipment and a 1.8 m antenna, has been developed. This tranportable earth station can be in operation within minutes of arriving on a site, and will be very useful for satellite news gathering. With a larger 2.2 m antenna the station can be used for videoconferencing. (Figure 4.23).

Radio Broadcasting

The use of the 14/12 GHz transmission bands (SCPC/FDMA) for high quality radio broadcasting, to small receive only terminals, is currently under development.

Figure 4.22 Pay TV Station

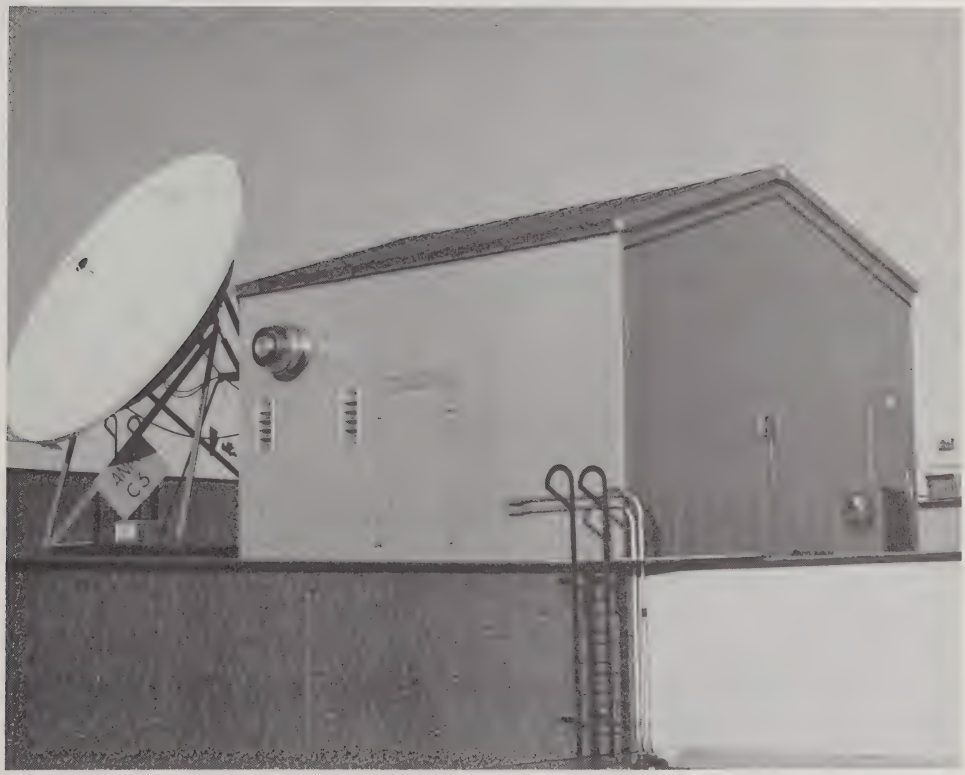


Figure 4.23 Transportable TV Station

Experimental Earth Stations

Direct Broadcasting

The 14/12 GHz RF channels on Anik B and Anik C have sufficient power to allow television to be received satisfactorily, although with somewhat reduced quality, by earth stations using very small (1.2 m to 1.8 m) antennas.

The size of antenna which is used depends on:

- location of the receiving earth station within the satellite beam (e.g. at beam centre or at beam edge),
- the bandwidth of the transmitted RF carriers,
- whether one or two RF carriers are transmitted in the RF channel,
- the minimum acceptable video signal-to-noise ratio.

Lower terminal costs, which are attractive for direct-to-home television distribution applications, result from the following factors:

- The antenna costs of a direct-to-home earth station are low because of the small antenna size.
- The direct-to-home earth stations are expected to be produced on a large volume basis using production techniques similar to those developed for consumer products.
- A relaxation in the baseband characteristics is permissible since no additional degradation due to terrestrial distribution would be included. As a result, less sophisticated circuitry and less expensive components can be used. Also, less effort is required in alignment, production and testing, and in preparation of maintenance documentation.
- Installation costs for a direct-to-home receiver may be less because of the smaller antenna and because it is expected that, in most cases, the labour will be provided by the owner.

Experiments in medium powered direct-to-home broadcasting were carried out in Ontario and British Columbia, under the sponsorship of the Department of Communications' Pilot Projects, on the 14/12 GHz channels of Anik B. An experimental receive station is shown in Figure 4.24.

Pilot Projects

Additional projects carried out included Telehealth (two way video), educational (1 way and 2 way), community communications in the North (video or voice transmit, voice return), low capacity telephone, low rate TDMA, low rate data transmission, multimode communications (mixture of video, voice and data) and the distribution of Telidon videotext to schools for educational purposes. Trials have also taken place using stable platforms designed to be used as antenna bases on floating oilrigs and very large ships (Jumbo tankers). Some of the experimental programs have been forerunners of full commercial services now carried or planned for the Anik C series of satellites.

Future Developments

Telesat currently has under consideration several experimental 14/12 GHz earth stations, including;

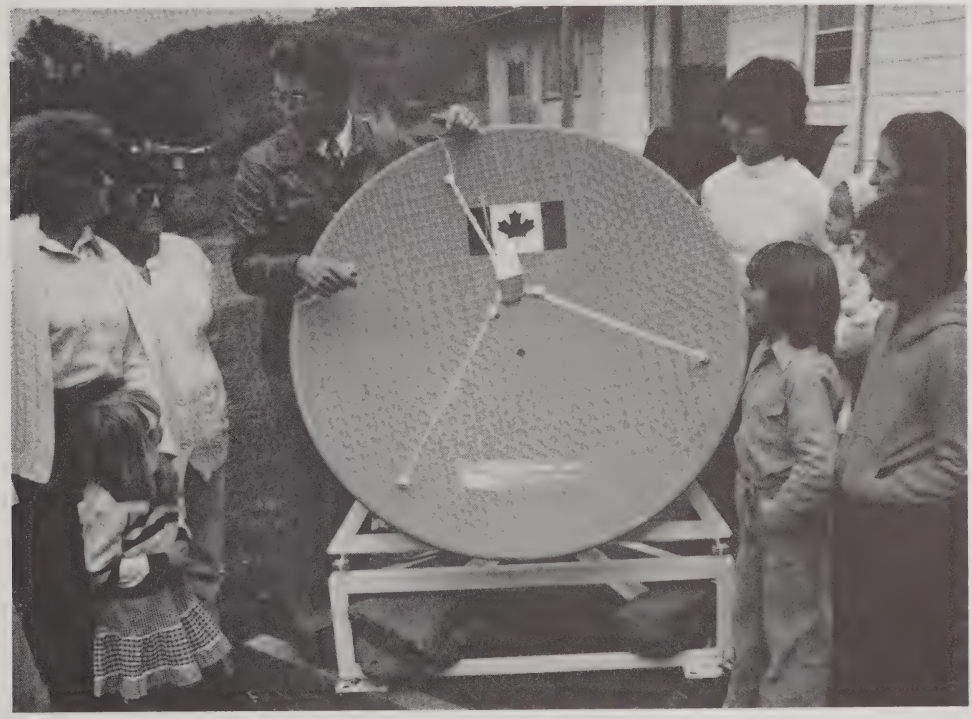
- a small, receive only, terminal for the reception of broadcast type signals, and
- a Thin Route station with up to six circuits.

Present plans call for a series of trials and field tests of these experimental terminals over the next few years using the Anik B or Anik C space segment facilities.

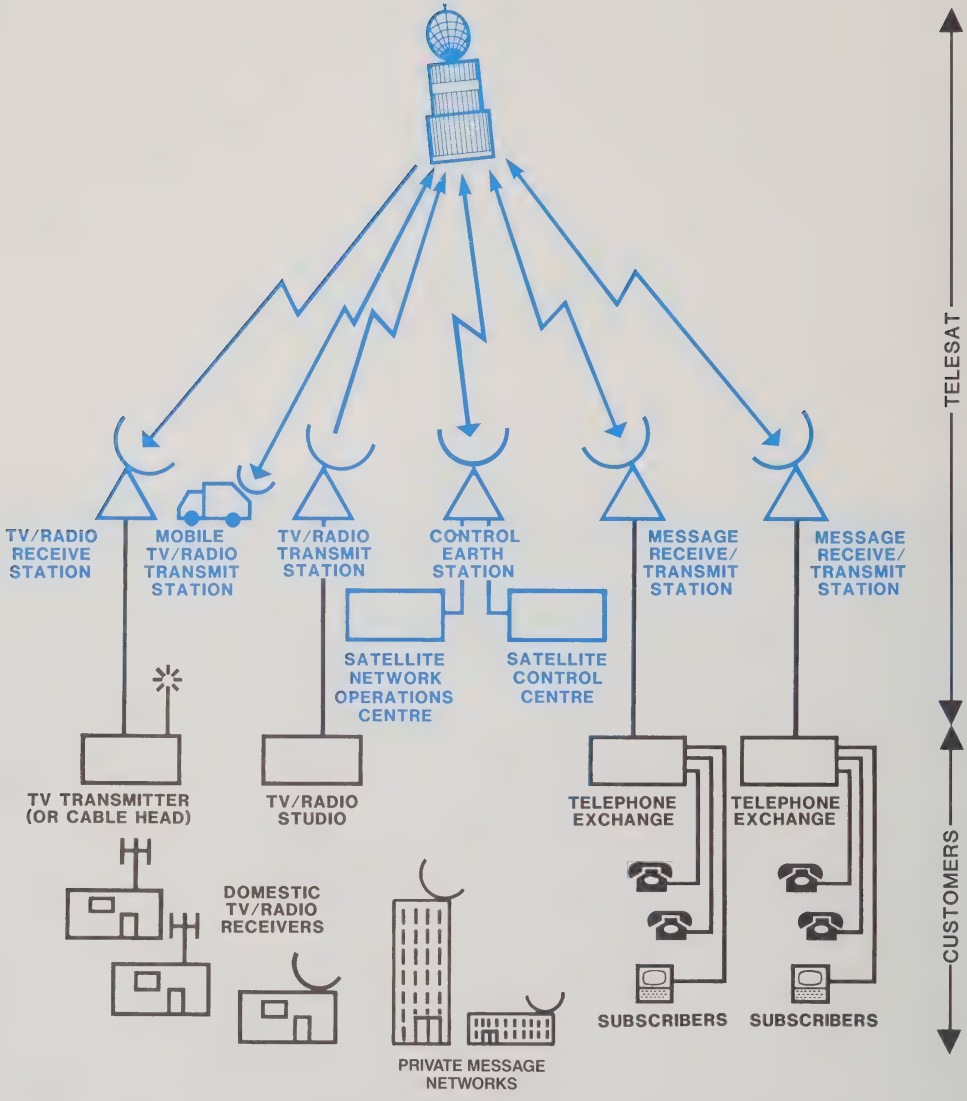
High Frequency Tests

In cooperation with Federal Government agencies, Telesat has been studying the transmission of radio waves through the earth's atmosphere at 28 GHz. Signals from the COMSTAR D3 and D4 satellites were received, and levels recorded, at two earth stations twenty-three kilometres apart. The data will be processed and used in studies of future satellite systems designs.

Figure 4.24 Experimental 14/12 GHz TV Direct Broadcast Earth Station



Chapter 5
Network Control Operations


TELESAT
CUSTOMERS
TV/RADIO RECEIVE STATION
MOBILE TV/RADIO TRANSMIT STATION
TV/RADIO TRANSMIT STATION
CONTROL EARTH STATION
MESSAGE RECEIVE/ TRANSMIT STATION
MESSAGE RECEIVE/ TRANSMIT STATION
SATELLITE NETWORK OPERATIONS CENTRE
SATELLITE CONTROL CENTRE
TV TRANSMITTER (OR CABLE HEAD)
TV/RADIO STUDIO
TELEPHONE EXCHANGE
TELEPHONE EXCHANGE
DOMESTIC TV/RADIO RECEIVERS
SUBSCRIBERS
SUBSCRIBERS
PRIVATE MESSAGE NETWORKS

Network Control Operations

5

Telesat Network Control Operations is divided into two major areas, Satellite Operations and Earth Stations Operations.

Satellite Operations

The elements of Satellite Operations are:

a) The Satellite Control Centre (SCC)

The Satellite Control Centre, (previously discussed in Chapter 3) is continuously manned and is the focal point of all satellite operations and activities. Here, satellite performance is monitored and the satellite commands generated for the purpose of battery management, stationkeeping manoeuvres and general housekeeping. Telemetry data from the satellites is routed to the Computer Centre (refer to Chapter 3) where it is available for further analysis and computation by the Satellite Control analysts and by Spacecraft engineers. All parameters reflecting the status of all satellites are displayed in the SCC.

b) The Tracking, Telemetry, and Command Stations (TTAC/TAC/KTAC/STAC)

The main station is colocated with the Allan Park Station (See Chapter 4). It is staffed by technologists who operate and maintain the specialized electronics hardware necessary to issue commands to the satellites and to collect telemetry data. Each satellite has a dedicated antenna (TAC 2, TAC 3, KTAC 1, KTAC 3 and the main communications antennas). During transfer and drift orbits of new satellites, the TTAC is used as the Western Hemisphere Tracking Station. As well as providing the above facilities, the TTAC station is used for routine ranging on all Anik A,C and D satellites, despinning the Anik A, C and D satellites if necessary and providing special test data.

Unmanned 14/12 GHz KTAC stations are colocated with the Huggett (Alta) earth station for ranging and to provide a backup despin pilot signal. An unmanned 14/12 GHz, Southern, KTAC Station (STAC) is located at Terre Haute (Indiana) for operational control of Anik C2 which is tilted approximately 0.5° South and 0.4° West.

Earth Station Operations

The operation and maintenance of all earth stations is carried out by Telesat personnel located in Ottawa and at five manned stations. In support are a number of maintenance agents under contract.

The earth station network is divided into three geographic regions (Figure 5.1); Earth Stations

Figure 5.1 Earth Station Group Areas

West (ESW), Earth Stations Central (ESC) and Earth Stations East (ESE). Each region is responsible for the operation and maintenance of those stations that lie within its boundaries. Earth Stations West is at Calgary, Alta, near one of the manned stations, Earth Stations Central is at Allan Park, Ont, and Earth Stations East is located at Company headquarters in Ottawa, Ont. There are three other manned stations, at Frobisher Bay, N.W.T., Harrietsfield N.S., and Lake Cowichan B.C.. The smaller, remote, sites are unattended and are maintained either by Maintenance Agents (local technical personnel usually from a telecommunications company) or by Local Agents (local non-technical people).

Field support, in the form of standardized procedures, safety and security, technical training, management information systems and project coordination and planning are provided from Company headquarters.
An order wire system is available via satellite between Allan Park and the major 6/4 GHz message stations (Frobisher Bay, Resolute, Harrietsfield and Hall Beach) using the 4-8 kHz part of the satellite baseband. In addition an order wire (using 8-12 kHz of the baseband) is shared with Telesat's customers between Allan Park, Frobisher Bay and Resolute. These order wires extend from the customers' premises at the remote location to their premises connected to Allan Park.

Alarm and supervisory systems have been installed at Television Transmit stations, Northern Telecommunications stations, the Facsimile Transmitting station, and the 14/12 GHz main stations . At each of these stations, a remote terminal is linked to a corresponding master terminal at a central monitoring point at Allan Park (Figure 5.2). Each system is independent and operates over leased data links or over order wire via a satellite. Each master terminal has two prime functions:

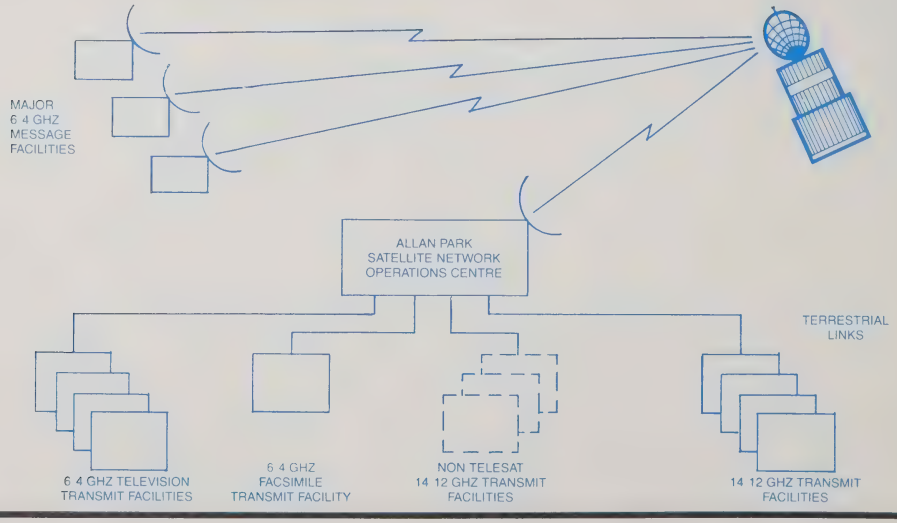
1. Monitoring of equipment status and alarms, and
2. Control of remote equipment.

Carriers from any station, via any Telesat satellite, received at Allan Park or Huggett, are automatically monitored. The Carrier Monitor Spectrum Analyzer at Allan Park is programmed to scan its intermediate frequency/radio frequency ports which are connected to test receivers, digitize the information, and display it. A spectrum analyzer at Huggett has the same function and its output is transmitted to Allan Park over a dedicated communications link. Should any monitored carrier change in level beyond pre-set limits, the operator is alerted and measurements are logged on a teletype.

At several remote message stations, a teletype channel, in a voice circuit, is used to relay basic station information to a manned station. There the data is displayed on a Line Monitor and any out of limits change is indicated by an LED and an audible alarm.

Thus Allan Park has an overview of the most vital data from all Telesat's message earth stations.

Figure 5.2 Earth Station Supervisory System



Satellite Network Operations Centre

Telesat's earth station network is part of a larger network involving customers' facilities and the backhaul facilities of other telecommunications carriers. Such a diverse system requires close and effective working arrangements between all concerned. The focal point in Telesat is the Satellite Network Operations Centre (SNOC) at Allan Park (Figure 5.3). Here, customers report any observed impairments or interruptions to their service. The SNOC oversees the detection, location and clearance of service troubles, and, in emergencies, coordinates service restoration by frequency reassignments, traffic reallocation or antenna reorientation. It also coordinates service releases for system maintenance and provides system status information to Company headquarters (Figure 5.4).

Figure 5.3 Satellite Network Operations Centre

Non Telesat Transmit Stations (14/12 GHz)

Customers, licenced to operate 14/12 GHz transmit earth stations to Anik C satellites, are required to obtain Telesat's approval of certain parameters of their transmissions and traffic plan. They must also allow some form of supervision and control for the protection of Telesat's satellite system.

Repair and Spares Depots

In general, field repair of modules is restricted to repairs of a simple nature. Normal practice is to isolate the faulty module or assembly and replace it. Most repairs are done at the Central Repair Depot at Allan Park, with some at manned locations including ESE (Ottawa) and ESW (Calgary). The main logistics and supply centre is at Allan park, but some critical spares are stocked at Ottawa, at the manned stations and at other subdepots. The subdepots reduce the detrimental effect of irregular and infrequent commercial transportation in the less populated areas of Canada.

Serviceability

Charts showing the average serviceability achieved over the last five years are at Figures 5.5 and 5.6.

Figure 5.4 Satellite Network Operations

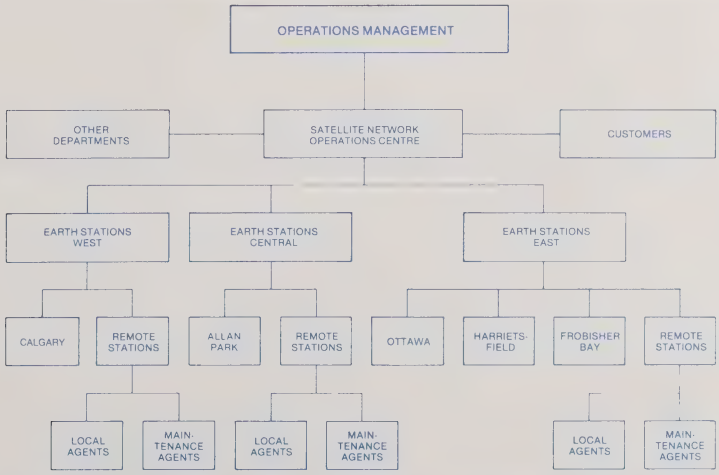
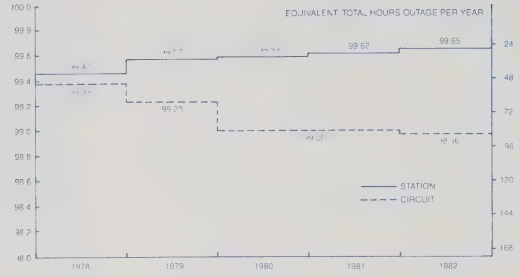
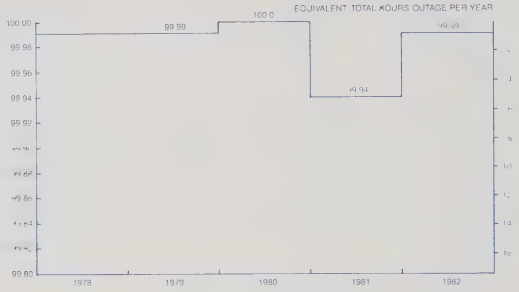


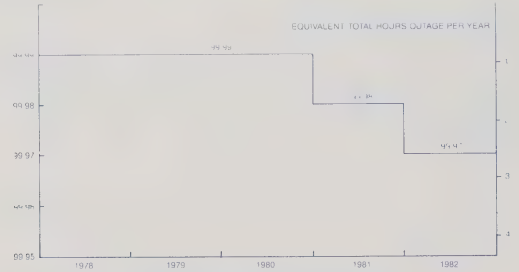
Figure 5.5 Message Serviceability



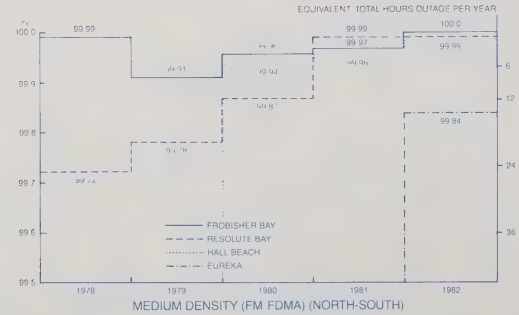
THIN ROUTE



MEDIUM DENSITY (PCM TDMA)

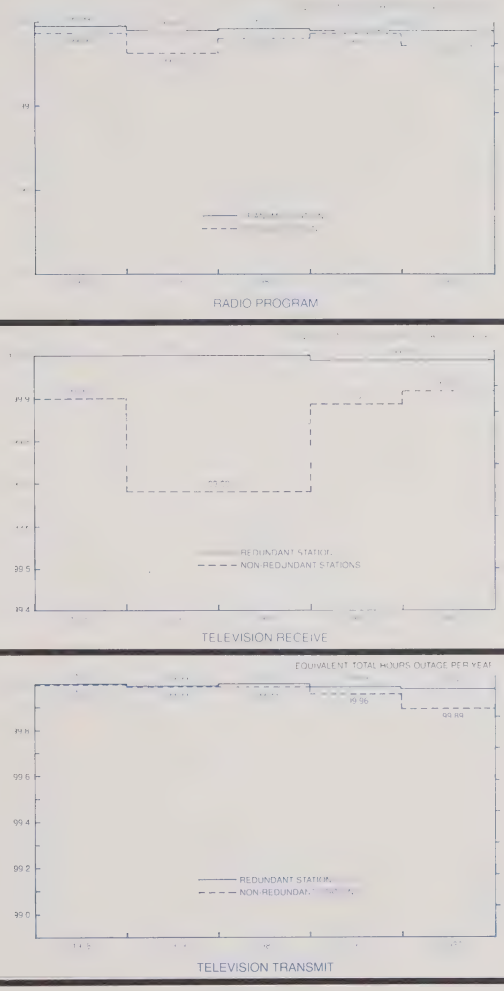


MEDIUM DENSITY (FM FDMA) (EAST-WEST)



MEDIUM DENSITY (FM FDMA) (NORTH-SOUTH)

Figure 5.6 Television/Radio Serviceability



Appendix "A"

Telesat's Major Contractors

The companies and organizations which have received major contracts from Telesat during the period 1970 to 1983, together with a brief indication of the nature of their contracts, are identified in the following table.

Andrew Antenna	Antennas
Automatic Electronic Systems	Supervisory Equipment
Bell Canada	Data Communications & Maintenance
Bell Northern Research	Network Control Software for the ISBN
Canadian Astronautics	Message Station Modification Kits
Canadian General Electric	Channel Units for Message Service
Canadian Marconi Ltd.	Test Equipment
CNCP Telecommunications	Data Communications & Maintenance
COMTEL	TDMA Equipment for the ISBN
Computel Systems Ltd.	Computation Services
Digital Communication Corp.	TDMA Study and Supply of System
Digital Telecommunications Ltd.	—Single Channel Transportable Earth Terminals. —Light Route TDMA, Earth Stations & Network Control Centre —Channel Units for Message Service
Ford Aerospace	TTAC Antenna Modifications
Goodwood Data Systems	Video Display System
Hewlett-Packard Canada	Computer Systems & Test Equipment
Hughes Aircraft Company	—Three Anik A Spacecraft & Associated Services —Three Anik C Spacecraft & Associated Services —Leased Eastern Hemisphere TT&C Services (EHTS) —Perigee Kick Stage Systems —HPAs —Major Subcontract on Anik D Spacecraft
L.N.R.	—Video Exciters —14/12 GHz Up and Down Converters
Mechron Engineering Products	Turbine Generator
Miller Communications Ltd.	Carrier Monitoring System
National Aeronautics and Space Administration (NASA)	Launching Services for Spacecraft
Northern Telecom	Major subcontract on Anik A Spacecraft
Oakes Mechanical Contracting Ltd.	Satellite Control Centre Complex
Philco-Ford of Canada Ltd.	Tracking, Telemetry & Command Station
Quindar Products Ltd.	—Television Network Control System —Lake Cowichan Supervisory System
Raytheon Canada Ltd.	—RTV Earth Stations —Message Communications Earth Stations —Transportable Earth Stations —TCTS Earth Stations —Direct Modulated 14 GHz Video Exciters

RCA Corporation	—Anik B Spacecraft —Anik B Eastern Hemisphere TT&C Services (EHTS)
RCA Ltd.	—Major Subcontract on Anik B —Main Television Receive/Transmit Earth Stations —Message Communications Earth Stations —Radio Equipment
Scientific Atlanta SED Systems Ltd.	Antennas and Receivers —Telemetry & Command Antenna (TAC2) —14/12 GHz Test Station —Television Receive Earth Stations —Frontier Television Receive Earth Stations —Message Communications Earth Stations —Far North Earth Stations —Major Subcontract on Anik C program
Spar Aerospace Ltd.	—Major Subcontract on Anik A Spacecraft —Major Subcontract on Anik C Spacecraft —Two Anik D Spacecraft
Varian Associates	TWT, Klystron & Power Supply Spares
Willowglen Systems Ltd.	Distant Monitor & Alarm System

Appendix "B"

Glossary of Terms

APOGEE KICK MOTOR (AKM)	The rocket motor used at the apogee of a Transfer Orbit to direct a satellite into its Drift Orbit.
ATTITUDE	The position of a satellite's axes measured against a set of reference axes. Usually measured as pitch, roll, and yaw.
CHANNEL	A single path for transmitting radio signals in one or two directions. The paths may be separated from other similar paths by frequency or time division. In the Telesat system a channel is also used to describe a band of frequencies (eg. Anik A3 Channel 1).
DEMAND ASSIGNED MULTIPLE ACCESS (DAMA)	A system in which circuits in a channel are allocated on an as-required basis and are not permanently allocated.
DRIFT ORBIT	The orbit followed by a satellite, after the firing of the Apogee Kick Motor, as it drifts towards its allotted operational station.
DS-3 BIT STREAM	672 digital circuits.
EQUIVALENT ISOTROPIC RADIATED POWER (EIRP)	A measure of the power available from an antenna. The product of the antenna gain and the input power.
FEED HORN	A means for directing radio waves on to an antenna reflector, or subreflector, and vice versa.
FREQUENCY HOPPING	A technique by which an earth station changes transmission frequency to access different satellite channels. This is required when the satellite has several spot beams and the transmission has to be directed to different areas (i.e. different spot beams).

GAIN/TEMPERATURE (G/T)	A measure of the receiving ability of an antenna/LNA combination.
GEOSTATIONARY ORBIT	The orbit of a satellite such that, from earth, the satellite appears to remain at the same azimuth and elevation. (ie. a geosynchronous orbit in the equatorial plane.)
OMNI DIRECTIONAL ANTENNA	An antenna which radiates in all directions. Used on a satellite from launch until the communications antenna is in use.
PERIGEE KICK MOTOR (PKM)	The rocket motor used to inject a satellite into its transfer orbit after launch from the Orbiter or the 3920 Delta launch vehicle.
PITCH	The movement of a satellite, about an axis through its CG, which causes the antenna footprint to move East and West.
POLARIZATION	The restriction of the transverse vibrations of an electromagnetic wave to a fixed (horizontal or vertical) or a varying plane (circular).
ROLL	The movement of a satellite, about an axis through its CG, which causes the antenna footprint to move North and South.
SATELLITE CONTROL CENTRE (SCC)	The centre from which control of the satellites is exercised.
SITE DIVERSITY	The use of two or more terminals, separated by some distance, at a station to overcome the problems of fading.
SPIN STABILIZED	The method of stabilizing a satellite by means of spin (cf. a top).
SPOT BEAM	A satellite antenna beam which provides service to only a part of the satellite's total coverage.
TIME DIVISION MULTIPLE ACCESS (TDMA)	A communications system which allows two or more earth stations to send and receive signals over one channel at the same frequency. The transmissions are sent in bursts separated by very short time intervals.
THREE AXIS STABILIZATION	A system of satellite stabilization in which its axes remains fixed with respect to earth.
THRUSTERS	Devices in which propellant is burnt, or disintegrates, to produce a controlled force in a selected direction.
TRANSFER ORBIT	The orbit of a satellite between the firing of the Perigee Kick Motor and the firing of the Apogee Kick Motor.
TRANSPONDER	A device which receives, amplifies and retransmits RF energy.
TRANSPONDER HOPPING	The same as frequency hopping.
TRAVELLING WAVE TUBE AMPLIFIER (TWTA)	A wideband amplyfing device in which power is added to a carrier as it propagates down a tube. Limited power output but light in weight.
VOICE ACTIVATION (VA)	A communication system in which the carrier is not transmitted unless a signal is present.
YAW	The movement of a satellite about an axis through its CG, which causes the antenna footprint to rotate clockwise or anti-clockwise.

Photographic Credits

Figure 2.1	Hughes Aircraft Corp.
2.3	NASA
2.13	Hughes Aircraft Corp.
2.24	NASA
2.27	NASA
2.29	NASA
3.5	Telesat Canada
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